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A review of the pharmacological activities of honey

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ABSTRACT

Background: Since ancient times, Honey has been highly prized and widely used by humans for both nourishment and medicinal purposes. The sweet substance known as honey is mostly made by honey bees from the nectar and parts of plants. Because of its amazing therapeutic abilities due to its Antioxidant, Antibacterial, Anti-inflammatory, Antiproliferative, Anticancer, and Antimetastatic properties, honey is and has been used for a wide range of illnesses in traditional medical systems and in majority of ancient cultures and religion for millennia.

Methods: An online search of relevant databases for the pharmacological activities of honey was undertaken. Websites such as PubMed, Google Scholar, Web of Science were utilized. The characteristics and the types of honey were considered in this review. Also, the value and significance of honey was discussed.

Results: The review uncovered numerous aspects of honey such as- Description/Composition of honey, History of honey, Religious significance of honey, Income analysis of honey production, Types of honey, Physical properties of honey, Thermal characteristics of honey, Shelf life of honey, Preservative properties of honey with greater emphasis on the Therapeutic properties of honey.

Conclusion: Numerous modern scientific literature point to the potential benefits of using honey in the management of wounds, diabetes, cancer, diarrhea, urinary tract infections, infertility, arthritis, eye problems, asthma, and a host of other conditions including neurological, gastrointestinal, respiratory, and cardiovascular disorders. The two main class of bioactive compounds found in honey are flavonoids and polyphenols, both of which have antioxidant properties.

Key words: Honey, pharmacological activities

1.0 INTRODUCTION

Honey is a naturally sweet and viscous liquid made by different honey bee species (*Apismellifera*, *Apisceranaindica*, and *Apismellipodae*) from the juice of flowers and secretions of living sections of plants. The technique by which these bees create honey is the same around the world, but the variations in honey's physical and chemical characteristics are mostly caused by its botanical and geographic origins (Samarghandian et al; 2017). Honey is formed from a wide range of flora components, primarily from plants, as evidenced by the variation in taste, flavor, aroma, and color [1]. This significant variation is also clearly visible in the content and nutritional benefits of honey. By inverting a large percentage of the nectar's sucrose sugar into the sugars levulose (fructose) and dextrose (glucose) and by removing extra moisture, nectar is developed into honey. A honeycomb, a double layer of uniform hexagonal

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cells made of beeswax (secreted by the bees), is used to preserve honey in the beehive or nest.

1.1 Description of honey

The chemical components of honey are crucial because they determine it's medicinal, nutritional, and granulation properties including its shelf life and texture. All kinds of honey have the same basic ingredients, however natural honey possess a very different chemical makeup and physical characteristics based on the kind of plants the bees graze on. Natural honey's characteristics also differ based on the different meteorological conditions encountered during production, the type or types of plants used as the source nectar, the circumstances for processing and storing, beekeeping practices for collecting and extracting honey, and local vegetation [2]. Natural honey ranks as one amongst the most well-liked goods because of its extraordinary nutritional and healing properties, which are connected to the interactions of the numerous groups contained in it [2]. Everywhere in the world, mercantile honey samples are available for purchase, but the level of quality or nutritional value of these samples varies widely based on factors including location, production season, nectar source, processing, packaging, and storage durations. Sugar and water are the primary constituents of natural honey, and the monosaccharides fructose and glucose are what give it its sweetness [3]. Proteins, minerals, organic acids, vitamins, lipids, esters, and enzymes are other components [4]. It is thought that honey contains flavonoids, phenolic acids, enzymes, vitamins, and minerals like copper and iron that give honey its redox properties [5]. These elements provide a wide range of medicinal and nutritional advantages despite only being present in trace levels. The biological and calorific value of honey is high. Because honey has different uses, it is important to thoroughly examine it and create value ranges for its many components and characteristics. The honey industry has demonstrated a great deal of interest in these elements since they have an impact on the honey's granulation, texture, flavor, nutritional value, and storage quality including its ability to be used medicinally. Honey is water-soluble and contains around 18% water and 80% sugar [6]. The typical way for assessing honey is through a physicochemical analysis of its components. Understanding the features of honey makes it possible to package and store honey the right way to preserve its qualities and flavor. It also provides information on the nutritional and energetic value, in addition to the possibility of honey fraud. In practice, honey possess a few more calories per serving than sugar: 21 calories as opposed to 16 calories for a teaspoonful of honey. In addition, honey is a kind of added sugar, similar to sugar and agave syrup, when used to sweeten tea or baked products. As a result, just like any other added sugar, honey should be consumed in moderation and with prudence. According to American Heart Association (AHA), Women and children should limit their intake to six (6) teaspoons (24 grams) per day, while males should limit their intake to nine (9) teaspoons (36 grams) per day [7].

1.2 History of Honey

Globally and In Nigeria Since 2100 BC, and when there was no written history, honey existed and has been in use. It was mentioned in cuneiform writings from India, Egypt, Sumer, and Babylon as well as Sumerian and Babylonian literature. Fossils of honey bees go back about 150 million years. It was the earliest and most widely utilized sweetener used by humans, and its name is obtained from the English word Hunig [8]. Bee commonly appeared as a sign of royalty in Egyptian hieroglyphs. Ancient Egyptians used honey as a sweetener, a gift for their deities and also as an ingredient in embalming fluid. As offerings to the deities or divine beings, the Egyptians, Greeks and the Romans prepared honey cakes. Honey was viewed by the Greeks as both a food and also as a healing medicine [9]. Greek recipe books are replete with honey-based desserts and sweetmeats. In the fifth century BC, cheeses were combined with honey to form cheesecakes, which were "steeped most thoroughly in the rich honey of the golden bee," according to Euripides [10]. Honey and beeswax production rose significantly to supply the demand for church candles when Christianity was founded. Evidence of honey consumption was found among the Nok (Kaduna state) culture's people 3,500 years ago based in an investigation of clay pot residue [11]. Wall reliefs from 2,600 B.C.E. in Egypt, which is not too far from Nigeria, represent beekeeping in great detail. Throughout the history of civilization, honey has been

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produced by honeybee colonies for human consumption. According to prehistoric art, the first known instance of man actively pursuing bees by climbing ladders or ropes is depicted in a cave picture in Spain that dates to roughly Ten Thousand years before the present [12]. If the interpretations are true, other bee-related rock art has been found all across the world, from southern Africa to India and Australia [13]. One illustration from the Matobo Hills rock shelter in Zimbabwe, a World Heritage Site, even shows a person burning out a beehive. Additionally, beeswax remains were found on clay pots from about 8,500 years ago in Turkey. The formal management of honey bee colonies for the aim of producing commercial honey is a relatively recent development. It is clear that the Ancient Egyptians kept bees only to produce honey, at least 2,500 years in the past. The legacy of commercial beekeepers' pioneering attitude is the practice of growing bees in mobile comb hives, which is essentially what modern bee farming or keeping bees is now. Modern bee farming, which essentially involves growing bees in moveable comb hives, is a legacy of the pioneering spirit of professional beekeepers like Reverend Lorenzo I. Langstroth, who invented a hive in 1852 and whose design is still commonly used today [14]. The ancients greatly depended on honey for its healing qualities because they had few other options for sugar. Honey has had a significant historical impact because of its therapeutic qualities and versatility.

1.3 Religious significance of honey

In ancient Greek religion, Zeus and the twelve Gods of Mount Olympus ate honey as nectar [15]. One of Hinduism's Five life-giving elixirs is honey (Madhu) (Panchamrita). Madhuabhisheka, a ceremony performed at temples, includes pouring honey over the gods. The scriptures of the Vedas and additional historic scriptures mention honey as a wonderful food and medicine [16]. The Hebrew New Year, Rosh Hashanah, is symbolized by honey. To welcome a delicious new year, slices of apple are dipped in honey and served with the holiday feast. In Hebrew bible, honey is frequently referenced [17].

Exodus, Judges, Matthew, and Proverbs are a few of the Christian scriptures that discuss the significance of honey and bees. In the Bible, the holy scripture of the Christian religion, King Solomon is quoted thus: in Proverbs 24:13 " My son, eat honey, for it is good, and the drippings of the honeycomb are sweet to your taste ". In fact, the Bible claims that John the Baptist survived for a long time on a diet that included "wild honey" while he was in the desert [9]. Samson discovered a swarm of bees and honey in a lion's carcass in the Book of Judges (14:8). Biblical law covered sacrifices made to God in the temple. "Every grain offering you bring to the Lord must be made without yeast, for you are not to burn any yeast or honey in a meal offering for the Lord," according to the Book of Leviticus (2:11). The Promised Land is referred to in the Book of Exodus as a "land that flows with milk and honey" (33:3) [9]. An entire chapter "Surah al-Nahl," which translates to "Chapter of the Honey Bee," is found in the Holy Qur'an. The usage of honey was ardently encouraged by the Prophet Muhammad. According to Chapter 16 of the Holy Qur'an: "And the Lord inspired the bee, saying: Take your habitations in the mountains and in the trees and in what they erect. Then, eat of all fruits and follow the ways of your Lord made easy (for you)'. There comes forth from their bellies a drink of varying colors wherein is healing for men. Verily in this is indeed a sign for people who think" (28, 29) [18].

1.4 Income analysis of honey production in the world

About 360,000 metric tonnes of honey are imported annually in Nigeria which costs about 838 billion naira.
The value of the world's honey market exceeded $8 billion U.S. Dollars in 2021 and is expected to grow over 12 billion U.S. Dollars by 2028. In Nigeria, a liter of honey currently sells for averagely between 4,000 and 5000 naira. The total revenue of honey production in Ikwuano local government area in Abia state Nigeria, following the data

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collected was N5, 460,000 per year [19]. In Nigeria, the production of honey has been observed to have the ability to lift households out of impoverishment and create jobs [20]. The COVID-19 pandemic has had an unusual and shocking impact on the world, and honey has been in higher demand than expected in all regions compared to pre-pandemic levels. Based on this analysis, the global market exhibited a 9.0 % increase in 2020 compared to 2019. In 2020, the top exporters of honey were New Zealand ($328 million), China ($229 million), Argentina ($175 million), Germany ($155 million), and Ukraine ($140 million). The United States ($419 million), Germany ($293 million), Japan ($176 million), the United Kingdom ($136 million), and France ($123 million) were the top honey importers in 2020.Between 2019 and 2020, the exports of honey grew the fastest in New Zealand ($91.3 million), Brazil ($30 million), Argentina ($26.1 million), Poland ($25.3 million), and Spain ($22.1 million). Between 2019 and 2020, the fastest-growing importers of honey were Germany ($59.3 million), Japan ($37.9 million), Saudi Arabia ($28.8 million), Poland ($23.5 million), and the United Kingdom ($16.5 million) (The Observatory of Economic Complexity (OEC) 2022)

2. TYPES OF HONEY

Flavor, and the floral source, color, region of production (regional honeys), as well as the packaging and processing methods used, are all utilized to categorize honey.

2.1 Floral Sources

Following the kind of nectar used to make it, honey can be divided into several categories [21].
These variations could be caused by the quantity and quality of ingredients utilized in the manufacturing of honey, such as nectar, pollen, and so forth. It is possible to pinpoint the main plant nectar source used in honey production using the rheological and melissopalynological characteristics of honey. Sources include:

2.1.1 Monofloral Honey

This honey is largely obtained from the juice of a single kind of flower. Because the primary nectar sources of various monofloral honeys vary, each variant has a special flavor and color. Beekeepers keep beehives in areas where the bees have access to as few varieties of flowers as possible so as to create monofloral honey. Only a small part of any monofloral honey will come from different kinds of flowers. Clover, orange blossom, sage, tupelo, buckwheat, fireweed, sourwood, cherries, and blueberries are typical North American monofloral honey examples. Thyme, thistle, heather, acacia, dandelion, sunflower, lavender, honeysuckle, and kinds of lime and chestnut trees are a few common examples of monofloral honey from Europe. Citrus (especially orange blooms), cotton, and clover are a few examples from North Africa [22].

2.1.2 Polyfloral Honey

The juice of different kinds of flowers is used to make polyfloral honey, also known as wildflower honey. The taste can change from year to year, and the aroma and flavor can be more or less potent depending on which flowers are in bloom [23].

2.1.3. Blended Honey

This is a combination of two or more types of honey, each with unique floral sources, colors, flavors, densities, and origins [23].

2.2 Packaging and processing

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Honey is also divided into groups based on the packaging and production methods used. Honey is typically packaged in its well-known liquid form, but it can additionally be sold in different forms and processed in different ways. In terms of packaging and processing, there are several kinds of honey, and they include:

2.2.1 Comb Honey:

Comb honey is honey that has not been removed from its original honeycomb of hexagonal beeswax cells and is meant for human consumption. It is exactly how honey bees produced it; it hasn't undergone any processing, filtering, or alteration. In honey supers, comb honey is gathered using common wooden frames. Before packaging, the frames are gathered and the comb is divided into pieces. Cut-comb honey is another name for comb honey that has been gathered in the traditional way [24].

2.2.2 Raw honey

If it hasn't been extracted, settled, or strained from the beehive, its pure honey without added heat (however some honey that has been "minimally processed" is frequently branded as raw honey). Raw honey may contain a tiny amount of pollen and/or wax [25].

2.2.3. Strained honey

This honey has not had pollen, minerals, or enzymes removed; instead, it has been passed through a mesh to remove various impurities, such as propolis fragments and other particles [26].

2.2.4. Filtered Honey

All or most of the microscopic particles, pollen grains, air bubbles, and other materials that are frequently found in suspension have been removed from filtered honey. In order to more readily flow through the filter, honey is often heated to 66–77 °C (150–170 °F) during the process [27]. The retailers like filtered honey because it crystallizes more slowly and is quite clear. In the most typical procedure, diatomaceous earth is added to honey heated to 60 °C (140 °F) and then run through filter paper or canvas until a cake comprising of earth's diatoms forms on the filter [22].

2.2.5. Crystallized honey (granulated honey)

When some of the content of the glucose in honey crystallizes as a monohydrate spontaneously from solution, the honey is said to be crystallized. Warming can make crystallized honey (or honey that has been acquired in a crystallized form) liquid again [24].

2.2.6. Pasteurized Honey

Honey that has undergone pasteurization has been heated to temperatures of 72 °C (161 °F) or higher. Yeast cells are destroyed by pasteurization.

Additionally, it melts any honey microcrystals, delaying the start of obvious crystallization. But excess exposure also degrades the product since it raises the quantity of hydroxymethylfurfural (HMF) and lowers the actions of few enzymes, like diastase. Additionally, heat darkens the honey and alters its flavor and aroma [28].

2.2.7. Creamed Honey

Creamed honey has undergone processing to reduce crystallization. In the UK, it's also referred to as set honey, whipped honey, spun honey, churned honey, and honey fondant. The abundance of tiny crystals in creamed honey

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prevents the growth of larger crystals, which can happen in untreated honey. Additionally, the processing results in honey with a silky, spreadable quality [29].

2.2.8. Dried Honey

The moisture from liquid honey is removed to produce totally solid, non-sticky grains of dried honey. The use of drying and anti-caking chemicals may or may not be a part of this process. Dried honey is used in baked goods and as a garnish on desserts [30].

3. Color and Flavor

Depending on the nectar source that the honey bees visit, the color and flavor of the honey vary.
Honey's color can range from practically colorless to dark brown, depending on where the honey bees buzzed, and its flavor can be delectably mild or distinctly robust. According to the National Honey Board (2018) [23], light-colored honey has a milder flavor than dark-colored honey.
*Alfalfa***:** A lot of the honey produced in Canada and the US is made using purple blossoms. The honey has a mild flavor and scent and a light color [31].
Avocado: Avocado honey is made in California using avocado blossoms. Avocado honey is black in color and has a rich, buttery flavor [23].
*Blueberry***:** A light amber hue and a rich, well-balanced flavor are typical characteristics of honey, which is often made from the nectar of the tiny white blossoms of the blueberry shrub. Both Michigan and New England produce blueberry honey[23].
*Buckwheat***:** A Rich, dark flavor characterizes buckwheat honey. It is made in Minnesota, New York, Ohio, Pennsylvania, and Wisconsin in addition to eastern Canada. Buckwheat honey has been found to contain more antioxidants than some honeys that are lighter[32].
Clover: Clover honey has a mild and sweet flavor. Clovers are the plant species that generate the most honey in the United States.
The most crucial clovers for honey production are red, Alsike, and white and yellow sweet clovers. Clover honey ranges in color from watery white to light amber to amber due to variations in the type and location of the parent clover [33].
Eucalyptus: Eucalyptus honey, as one might expect from such a huge collection of plants, comes in a wide range of colors and flavors, however it frequently has a deeper flavor and a subtle medicinal perfume. Californian producers make it [23].
*Fireweed***:** A magnificent bee pasture is created by the perennial fireweed, which thrives in the Northern and Pacific states as well as Canada. Fireweed yields light-colored honey. Fireweed develops spikes of beautiful pinkish blossoms that reach heights of three to five feet in open woodlands [34].
*Orange blossom***:** Orange blossom honey is frequently made from a variety of citrus sources and has a light color and mild flavor with a fresh aroma and a light citrus taste.
In Florida, regions of Texas, and southern California, orange blossom honey is grown [23].
Sage: Sage honey has a moderate yet delicious flavor and is predominantly produced in California. It is light in color, thick in texture. Because it granulates very slowly, honey packers like to blend it with other honeys to slow down the process [23].
Tupelo: Tupelo honey is a high-quality honey produced in northwest Florida. It typically appears light amber with a greenish tint and tastes mildly peculiar.
Tupelo honey granulates relatively slowly as a result of its high sugar concentration [23].
Manuka: The Manuka shrub is the source of manuka honey (Leptospermum scoparium), a New Zealand-grown indigenous plant. Numerous investigations have shown that manuka honey has antibacterial properties against

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different bacterial infections [33].

All honey has antimicrobial qualities, but Manuka honey has significantly more potent antibacterial capabilities since it also contains non-hydrogen peroxide. Some studies suggest that Manuka honey can also increase the growth factors that white blood cells need to combat infection and repair tissue.

4. HONEY COMPOSITION AND PROPERTIES

4.1 Composition

Physical and chemical characteristics of honey vary based on the type, including moisture content, pH, total acidity, density, dynamic viscosity, refractive index, electrical conductivity, color, and relative amounts of reducing and non-reducing sugars, total sugars, water-insoluble solids, mineral composition, 5-hydroxymethylfurfuraldihyde content, diastase value, proteins, enzymes, and antioxidants [35]. The floral source is the main determinant of the constituents of honey, although other external elements, including the season, the environment, and processing, all have an impact [36]. There are at least 181 different compounds in honey, which is mostly made up of fructose (38%) and glucose (31%). Minerals (such as calcium, potassium, copper, iron, magnesium, manganese, sodium, phosphorous, and zinc), proteins, and vitamins (Ascorbic acid, Thiamine, Riboflavin, Niacin, Pantothenic acid, Pyridoxine). Honey also contains different small components, many of which are recognized to have antioxidant qualities. These include phenolic and flavonoid acids, certain enzymes (glucose oxidase and catalase), and amino acids (proline, glycine, valine, glutamic acid, aspartic acid, isoleucine, leucine, lysine, alanine, glutamine, threonine, arginine, tryptophan, etc.), with proline being the most prevalent and accounting for about 50% of the total amino acids in honey [35, 36]. The most crucial factor affecting honey quality is its water content, particularly when it comes to the possibility of spoiling from fermentation and granulation or crystallization during storage [37]. Only honeys with a moisture level of under 18% can be stored without much or any risk of fermentation. Under particularly humid or tropical conditions, the amount of moisture in honey might be higher than 18%. A trace number of enzymes are naturally found in honey and are added by bees at different stages of the production process. Diastase (amylase), which breaks down starch or glycogen into smaller sugar units; invertase (sucrose; glucosidase), which breaks down sucrose into fructose and glucose; and glucose oxidase, which turns glucose into hydrogen peroxide and gluconic acid, are the three primary enzymes in honey [36].

Table 1. Composition of Honey

Proximate and carbohydrates (g)		Mineral content (mg)		Vitamin content (mg)	
Water	17.1	Calcium	4.4 – 9.2	Ascorbic acid (c)	2.2 -2.4
Energy (Kcal)	304	Potassium	13.2 –19.8	Thiamin (B1)	< 0.006
Carbohydrates (total)	82.4	Copper	0.003 - 0.1	Riboflavin (B2)	< 0.6
Fructose	38.5	Iron	0.06 - 1.5	Niacin (B3)	< 0.36
Glucose	31.0	Magnesium	1.2 - 3.5	Pantothenic acid (B5)	<0.11
Maltose	7.2	Manganese	0.02- 0.4	Pyridoxine (B6)	< 0.32
Sucrose	1.5	Phosphorous	1.9 - 6.3		
		Sodium	0.0 – 7.6		
		Zinc	0.03 - 0.4		

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4.2 Physical properties of honey

The amount of water, the kind of flora used to make it, the temperature, and the proportion of the various kinds of

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sugars it contains all affect the qualities of honey. Fresh honey is a supersaturated liquid that normally dissolves at room temperature because it contains more sugar than water. Honey is a cooled solution at ambient temperature where the glucose separates into solid granules. This produces a semisolid solution of precipitated glucose crystals in a combination of fructose and other chemicals [38].

4.2. 1Phase transition

Depending on its chemical components, crystallized honey has a melting point between 104 and 122 °F (40 and 50 °C). Honey can either be in a "labile" state below this temperature, where it is filled with plenty of sugars to spontaneously crystallize, or it can be in a "metastable" state, where it is stable but unlikely to crystallize until a seed crystal is added. Numerous factors influence the crystallization rate; however, the fructose to glucose ratio is the main determinant [39]. While honey with a low proportion of glucose, like chestnut or tupelo honey, does not crystallize, honey that is supersaturated with a significant proportion of glucose, like brassica honey, will do so nearly immediately after collection. Some honeys may produce large crystals, while others may produce small crystals. Water content has an impact on crystallization as well, because a high dextrin composition and high water content will both prevent crystallization [40]. The speed of crystallization is also influenced by temperature, with the quickest development taking place between 13 and 17 °C (55 and 63 °F). If the honey is stirred, shaken, or otherwise agitated, crystal nuclei (seeds) tend to develop more quickly than if it is left still. However, between 5 and 8 °C (41 and 46 °F), microscopic seed crystal nucleation is at its peak. Therefore, at higher temperatures, larger but fewer crystals often form, whereas at lower temperatures, smaller but more crystals typically do form. Honey may be kept forever with its natural texture and flavor because it won't crystallize below 5 °C [40].

4.2.2 Viscosity

Honey is a supercooled liquid since it typically exists below its melting point. The combination of temperature and water content has a significant impact on the viscosity of honey. The higher the water content, the easier honey flows. With the exception of a few varieties, the composition of honey likewise has little impact on viscosity aside from the water concentration. A honey with a 14% water content typically has a viscosity of roughly 400 poise at 25 °C (77 °F), whereas a honey with a 20% water content typically has a viscosity of about 20 poise. Honey won't completely freeze even at very low temperatures. Instead, honey becomes more viscous as the temperature drops [41, 42]. The initial rise in viscosity brought on by temperature happens very gradually. Honey becomes more viscous at an accelerating rate as it cools, reaching 600 psi at 14 °C (57 °F). Honey has a very low surface tension despite its high viscosity. Electric conductivity Because it contains electrolytes in the form of acids and minerals, honey has varying degrees of electrical conductivity [43]. In order to assess the ash content of honey, electrical conductivity measurements are utilized. The way the varied types and qualities of honey react to light makes this distinction possible. The refractive index of honey varies depending on the amount of water it contains. A refractometer can be used to measure water content with ease.

4.2.3 Hygroscopy and Fermentation

A characteristic of honey is hygroscopy, or the direct extraction of fluid from the atmosphere. The relative humidity of the air affects how much water the honey will absorb. Considering that honey contains yeast, its hygroscopic nature necessitates that it be kept in sealed containers to avoid fermentation, which typically starts when the honey's water level exceeds 25%. The other elements in honey may be the reason why it tends to absorb more water in this way than the individual sugars would [39]. Honey is typically fermented after it has crystallized because, in the absence of glucose, the liquid portion is predominantly composed of a concentrated mixture of fructose, acids, and water, which gives the yeast a sufficient rise in the water percentage for growth. In order to kill any yeast, honey that will be stored at ambient temperature for an extended period of time is frequently pasteurized by heating it above 70

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°C (158 °F) [44].

4.2.4 Thermal characteristics

If cooked long enough, honey will caramelize, changing color and finally burning, just like all sugar compounds. Depending on the substance, caramelization starts at a different temperature, but it usually happens between 70 and 110 °C (158 and 230 °F). Acids included in honey serve as catalysts and lower the temperature needed for caramelization [45]. The dark colour of honey is connected to the little amount of amino acids that are contained in honey. When a Maillard reaction occurs, the amino acids are converted into very dark substances called melanoidins. At room temperature, the Maillard reaction takes several months to become visibly darker; but, when the temperature rises, the reaction speeds up considerably [46]. The reaction can be slowed down by preserving the honey at a lower temperature. Honey has extremely weak heat conductivity, which makes it take a long time for it to attain thermal equilibrium. When melting crystallized honey, if the heat source is too hot or not spread evenly, it is easy to get localized caramelization. However, compared to when it is at higher temperatures, honey will take a lot longer to liquefy when it is just at the melting point. At 104 °F (40 °C), melting 20 kilograms of crystallized honey can take up to 24 hours, while melting 50 kilograms could take twice as long. Heating at 50 °C (122 °F) will almost cut these timeframes in half [47]. The flavor, aroma, and other characteristics of many of the minor chemicals in honey can, however, be significantly altered by heating; hence, heating is often done at the lowest temperature at the shortest time [30].

4.2.5 Shelf life of honey

When it's stored properly, honey never goes bad. Although honey will eventually darken and/or crystallize, it is still safe to consume [48]. Metal or plastic containers may oxidize the honey, and heat may change its flavor, therefore, for best performance, store it away from any kitchen electronics that produce heat. Even more crucial is placing the honey in an airtight glass container to stop it from fermenting; also, honey will be ruined by moisture contamination, clean and dry equipment should be used when scooping from the jar. Bacteria cannot survive in honey because of the low moisture content [49]. Honey is also sufficiently acidic to kill the majority of germs and other organisms that ruin other foods. Honey is an organic substance so it will vary with time. However, it can endure for years and still be edible or even decades. Over time, honey's look, consistency, and flavor may all change. As long as the changes in the honey don't indicate fermentation, they are actually positive signs and demonstrate how excellent and unpasteurized the honey is. Honey is heated during pasteurization so as to kill the natural yeasts and increase its shelf life. Although it might help the honey stay transparent and attractive for a longer period of time and remove some naturally occurring dirt from the comb, it is not necessary for the food's safety as it affects the nutrients in the honey. Honey that is sold commercially has expiration dates or "best before" dates mainly as a guide for retailers to bring in fresher stock. However, should a jar with just few months left on its "best by" date be chosen, one can be confident that honey will be great for a very long time even though the majority of it will be sold well before that [49].

4.2.6 Preservative properties of honey

There exist three major characteristics as to why honey has a long shelf life: a higher content of sugar than moisture, antimicrobial enzymes produced by bees, and its acidic nature. Honey has a higher sugar content than moisture. Sugar accounts for 80% of a honey's composition, while moisture accounts for the remaining 18%. Microorganisms like fungus and bacteria can't thrive and reproduce in it thanks to its high sugar content. The osmotic pressure in honey increases as a result of its sugar content. Consequently, an osmotic effect results in forcing the water within the micro-organisms cells to flow out [50]. Additionally, because there is little water present, the high sugar concentration might interact with the water molecules in such a way that bacteria cannot survive. In summary, honey doesn't degrade since it contains less water and because there is insufficient oxygen in it for microorganisms to develop and multiply. Honey

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contains antimicrobial enzymes. The microbial enzyme found in honey is glucose oxidase, bees put enzymes into nectar to guard honey against microbes [51]. When the honey is mature enough, the glucose oxidase enzymes change the sugar in the honey to create gluconic acid and hydrogen peroxide. Bacteria are eliminated by the hydrogen peroxide. Honey is acidic in nature. Since honey's pH ranges from 3.2 to 4.5 and is on average 3.9, it can be quite acidic. Honey's acidic character is caused by gluconic acid, which is created as nectar ripens and after the bee secretes glucose oxidase into it. Due to their acidic nature, Honey is nearly uninhabitable by bacteria [51].

4.2.7 Deterioration of honey

Despite the reality that honey possesses an indefinite shelf life, it can deteriorate due to contamination, adulteration, improper storage, excessive crystallization, etc. Through both natural and artificial means, honey can become contaminated with bacteria [52]. Bacteria, molds, and yeast can be acquired from the air, dust, dirt, flowers, pollen, or the digestive system of bees. They cannot properly proliferate in honey and are only present in extremely limited numbers. Because honey has antibacterial characteristics, these natural microbes are not dangerous to one's health. The same cannot be stated in terms of lethality about C. botulinum, a naturally occurring honey contaminant. It is a neurotoxin that is safe for adults but, in extremely rare circumstances, can seriously impair a baby's nervous system if they are one year old or younger. In newborns, it can also result in paralysis and breathing problems. Honey contamination can also result from secondary interference [50]. It might be due to the tools employed by people, animals, insects, wind, or even water during processing. Given the time and price required to make it, businesses tend to adulterate honey so as to reduce production costs and create more of the commodity. Honey's antibacterial qualities pose the risk of being hampered by improper storage. The honey will become contaminated and deteriorate [53]. The moisture composition of honey will rise when it is exposed to sunshine, providing the bacteria with the means to develop and proliferate. Honey crystallization is a normal occurrence that does not represent a health risk when stored correctly. It only turns bad when it is allowed to crystallize for an extended period of time because more water will be released and fermentation will take place as a result. This will be seen when the honey turns whiter and appears opaque. Although it's not harmful, fermentation makes honey tasteless and changes its beautiful golden color. Instead of a clear golden tint, poor honey takes on a murky yellow hue, and the texture thickens until it becomes gritty [49]. The color turns white, and the texture hardens until it's eventually deemed "poor." The long-term crystallization of honey is what caused the entire process. Another sign of poor honey is when the honey darkens and loses its flavor and scent. This results from keeping honey in storage for a very long time. Even though it poses no health risks when eaten in this form, the meal is no longer desirable [54].

4.2.8 Therapeutic properties of honey

According to Meda et al., both the wider populace and practitioners of traditional medicine are starting to acknowledge honey as a reliable and effective therapeutic agent. Its antibacterial, anti-inflammatory, and antioxidant capabilities has been endorsed for their positive effects [55].

4.3 Honey as food

From ancient times to the present, honey has been one of the most popular and traditional sweeteners for meals [56]. It is a crucial source of carbohydrates and the only commonly accessible sweetener that gives our body power and energy. Honey contains carbohydrates, which the body can rapidly and readily digest and absorb into the blood for use as energy. In contrast to fructose, which is absorbed more slowly and provides continuous energy, glucose in honey is swiftly absorbed by the body and gives an immediate energy boost. This helps maintain muscle glycogen [57]. Sodium, calcium, potassium, magnesium, phosphorus, selenium, copper, iron, manganese, chromium, zinc, amino acids, and vitamins are among the other minerals and elements found in honey. Due to its rich nutritional profile and wide variety of nutrients (even in trace amounts), honey can be considered a complete meal. These nutrients aid

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in the digestion and absorption of these important dietary components as well as those needed for metabolism and other bodily functions.

4.4 Chemotherapy and wound management

Due to their antibacterial and antiseptic qualities, natural, unprocessed honeys from various sources are used all over the world to treat burns and other skin injuries [51]. Partial burns may heal 4-5 days faster with honey than with other dressings, according to preliminary research, post-operative infections may heal more quickly and safely with honey than with antiseptic and guaze. The removal of bacteria is necessary for an infected wound to heal because germs trigger an inflammatory response that can hinder or inhibit wound healing [58]. Honey, whether applied topically or taken internally, has been observed to hasten wound healing. With little chance of bacterial growth and no side effects that would hinder the healing process, honey produces a moist environment. Due to its high viscosity and protective barrier, honey helps prevent cross-infection [59]. Additionally, honey is acidic, which aids oxygen release from the area and encourage healing. The FDA has authorized the use of several medical-grade honey products for the treatment of minor burns and wounds.

4.4 1 Gastroenteritis

Infections of the digestive system are widespread and can affect people of any age. According to reports, honey has properties that can help prevent and treat gastrointestinal conditions like peptic ulcers, gastritis, and gastroenteritis. Helicobacter pyroli, the agent responsible for gastritis and peptic ulcers, is significantly inhibited by honey. Natural Honey (NH) protected laboratory rats' stomachs from alcohol, aspirin, ammonia, and indomethacin attacks. The preventive effect of honey has been attributed to two different processes. According to the first, honey's antioxidant capabilities are what are responsible for this effect [60]. In gastric tissues exposed to conditions like ulceration, NH was found to maintain or increase the level of non-protein sulfhydryl compounds (such as glutathione). The second mode of action suggested by some writers is that consumption of honey stimulates the sensory nerves in the stomach and that this proprioceptive impact is in reaction to capsaicin. This process includes a decrease in ulcer index, vascular permeability, and stomach muscle activity [60]. Natural honey has no effect on blood sugar levels, and a mixture of honey and water is effective for treating digestive problems. In cases of diarrhea, raw honey may have a calming effect on digestion. A study conducted on 150 children suffering from acute gastroenteritis revealed that the children who were given honey along with an oral rehydration solution recovered from diarrhea more quickly than the other group.

4.4.2 Diabetes mellitus

With 31% glucose, 38% fructose, and 1.5% sucrose, honey has a healthy amount of sugars. After intestinal hydrolysis, cane sugar effectively yields 50% of each sugar. Since honey has almost the same sweetness as granulated sugar when compared on a weight basis, it may be argued that honey offers the diabetic greater sweetening power at a lower "price" of glucose than granulated sugar [61].

4.4.3 Reproductive health

Traditional beliefs hold that honey may promote male reproductive health, as well as fertility and energy. It had been claimed that giving adult rat daily exposure to 5% Palestinian honey for 20 days improved spermatogenesis. In an in vitro study, in subnormal samples it was found that diluted Egyptian honey and royal jelly enhanced sperm motility [62].

4.4.4 Cardiovascular effects and eye care

Honey has been demonstrated to reduce cardiovascular risk factors in both healthy people and patients who have elevated risk factors [36]. Furthermore, honey is suggested as a natural remedy for corneal problems, cataracts, pink

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or red eyes, dry and itchy eyes, and eye infections. Because honey has anti-inflammatory effects, it is utilized as an excellent eye drop. Such characteristics can treat a number of viral and inflammatory corneal diseases. We can use honey to protect our eyes from computer radiation, weariness, and redness [63].

4.4. 5 Weight loss and skin care

Regular honey consumption can be highly beneficial for weight loss. It has enzymes that speed up metabolism and increase digestion, both of which help people lose weight [64]. When combined with other components, honey's antibacterial properties can be hydrating and nourishing for the skin [65].

4.4.6 Cough and throat irritation

When it comes to treating children's coughs, honey doesn't seem to be any more effective than dextromethorphan [66]. Additional studies have backed the use of honey for treating kids. When it comes to treating coughs and sore throats, especially in children, there is no evidence that honey is less beneficial than a prescription medication. Buckwheat honey, in particular, aids in cough relief. A single dose of buckwheat honey was just as beneficial as a single dose of dextromethorphan in treating nocturnal cough and promoting sound sleep in a study involving 105 kids [67].

4.4.7 Antimicrobial activities

Traditional and herbal medicine practitioners have utilized honey as an antimicrobial agent. The antibacterial properties of honey were originally proven by the Dutch scientist Bernardus Adrianus van Ketel in 1892. [68]. Since then, a great deal of research has demonstrated that honey possesses broad-spectrum antibacterial activity against gram-positive and gram-negative bacteria, although effectiveness varies greatly amongst different honeys [69]. The spread of bacteria that are resistant to antibiotics in recent decades has reignited interest in studying honey's antibacterial properties. Methylglyoxal, hydrogen peroxide, and royalisin are components of honey that are being investigated in the early stages for potential antibiotic usage. Additionally, honey is a supersaturated sugar solution, which means that there is little to no water left behind to enable the growth of germs. Sugars have a high affinity for water molecules (bacteria and yeast) [70]. As a result, the microorganisms dry out and eventually die. However, it has been discovered that hydrogen peroxide, which is formed when the enzyme glucose-oxidase oxidizes glucose when honey is diluted, is responsible for the majority of the antibacterial action [71]. Most of the time, heat or the presence of catalase can quickly destroy the peroxide activity in honey [72].

4.4.8 Anti-inflammatory activities

Additionally, studies have demonstrated that honey enhances wound healing, lessens scar size, and promotes tissue regeneration [73]. Although inflammation is an essential component of the body's normal response to an illness or injury, it can hinder recovery or even do more harm if it persists for an extended period of time. The generation of free radicals in the tissue is the most detrimental effect of severe inflammation. Since inflammation is what sets off the chain of cellular events that results in the production of growth factors that regulate angiogenesis and the proliferation of fibroblasts and epithelial cells, certain leucocytes that are stimulated as part of the inflammatory process are the ones who first produce these free radicals [73]. They can be very harmful and degrade lipids, proteins, and nucleic acids, which are crucial for all cells to operate. Nonetheless, there is no adverse side effect and a solid clinical basis for honey's anti-inflammatory properties.

4.8.9 Anti-oxidant activities

It has been shown that honey has a considerable antioxidant content, which is quantified as its capacity to scavenge

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free radicals. Honey's antioxidant capacity is defined as its ability to reduce oxidative reactions in the human body. An atom, molecule, or compound that is very unstable due to its atomic or molecular structure is known as a free radical. As they try to combine with other molecules, atoms, or even single electrons to form a stable complex, free radicals are exceedingly reactive [74]. As a result, in many different kinds of organisms, reactive oxygen species (ROS) and free radicals lead to molecular changes and gene alterations. It is generally recognized that many diseases are brought on by oxidative stress [75]. Because oxygen free radicals are involved in a variety of elements of inflammation, these antioxidant properties may be at least partially responsible for their anti-inflammatory effects [76].

The antioxidants in honey are predicted to scavenge free radicals to lessen the degree of damage that could otherwise occur, even if they do not directly decrease the inflammatory process. Honey's anti-oxidant properties work by preventing the growth of free radicals, which are ions of metals like iron and copper that stimulate their creation. Common components of honey, such as flavonoids and other polyphenols, may impound these metal ions in complexes, limiting the initial production of free radicals. The phenols, including quercetin, hesperetin, and chyrsin, as well as the Maillard products known as melanoidins, are the primary antioxidants in honey [76],

5. CONCLUSION

There is ample data both physical and theoretical, showing the efficacy of honey in disease management. Therefore, the utilization of honey in modern day medicine, clinical wards and homes is highly recommended and more research should be carried out and documented on other pharmacological uses of honey.

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