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Review

Natural Honey (Raw Honey): Insights on Quality, Composition, Economic and Health Effects: A Comprehensive Review

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Abstract: Natural honey is one of the most significant foods produced and consumed globally, it has pleasing sensory characteristics such a light colour, as well as a recognizable flavor and aroma. In addition, natural honey has been associated with potential biological properties since it contains organic acids, sugars, minerals, enzymes, phenolic, volatile compounds, methylglyoxal, amino acids, and vitamins. All of these features make this viscous substance extremely desirable by consumers for health and wellness purposes and likewise by manufacturing industries for production purposes thus increasing its market value. Since honey plays a vital role in balancing human nutrition being a better alternative to sugar, and further serves as a natural raw material in most industrial products the world over, its socio-economic importance to human development and industrial output cannot be overemphasized. The income generating and job creating capacity of the honey industry has been beneficial both to corporate organizations and various governments of the world. It is therefore the aim of this study to provide information on the quality, composition, health effects and economics of this high value viscous liquid.

***Keywords*:** natural honey, adulteration, authenticity, health

1. Introduction

Honey is a natural mixture utilized in both food and complementary medicine because of its various bioactive properties. If this natural product is not exposed to heat treatment but left in its natural state, it is called raw honey. Raw honey however, easily gets transformed from the viscous liquid into a crystallized form. Heating and filtration methods are employed to prevent honey from crystallizing and these methods eventually turn raw honey into the processed form [1]. Honey has been used as medicine for thousands of years, and its chemical composition changes depending on the type of flowers used to make it, the season, the weather, and the methods used to prepare it [2]. Current science

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has validated the special nutritional and therapeutic advantages of this sweet and viscous material [3] as it possesses therapeutic potential both for systemic and topical applications. Some honey varieties that show noteworthy levels of antioxidants and antimicrobial activity are known as medicinal or apitherapeutic honey [4]. Vitamins and polyphenols contained in honey are accountable for its apitherapeutic properties. Pine, oak, chestnut and Manuka honey in addition to been dark-colored are also the most frequently utilized natural agents for medicinal food purposes [4]. Furthermore, Honey has an amazing capacity to destroy germs. It has been proven for example to be efficient against a wide range of bacteria, including common ones like *Salmonella* and *E. coli* [5]. At least one type is effective against the *staphylococcus* bacterium. Mad honey is another variety of honey so named because of its poison characteristics. It is produced when bees feed on the nectar of *R. ponticum* and *R. luteum* (Rhododendron flowers) and causes poisoning upon consumption. Nonetheless, mad honey is still been produced traditionally and sold to serve for an alternative medicine against various health aliments, like high blood glucose, pain and also to act as a sexual stimulant [4]. Topically, honey has been shown to be effective in the treatment of numerous skin issues, such as burns, wounds, ulcers, bedsores, acne, and burns [6]. Since it reduces blood pressure and the risk of cardiovascular events including heart attacks and strokes, honey's antioxidants are also advantageous to cardiovascular health [3]. In addition, antioxidants may help maintain healthy eyes and perhaps reduce the chance of developing some cancers [7]. It has been noted that honey is a powerful immune system booster due to its high levels of amino acids, vitamin B6, thiamine, niacin, riboflavin, and pantothenic acid; however, the specific amounts depend on the honey's floral origin and quality [8]. Significant levels of other minerals, including calcium, copper, iron, magnesium, and manganese, are also present in honey [9]. Its copper and manganese concentrations are primarily responsible for its extraordinary ability to increase hemoglobin production in the body [9]. According to Ayurvedic scriptures, it aids in regulating hemoglobin and red blood cell counts (RBCs) [10].

According to [11], honey contains a number of enzymes, including oxidase, invertase, amylase, catalase, and many others. Invertase (saccharase), diastase (amylase), and glucose oxidase are the three enzymes that are most prevalent in honey [12]. They are essential to the conversion of sugar into honey [13]. According to [11] the enzyme glucose oxidase breaks down glucose into gluconic acid, which helps the body absorb calcium, and hydrogen peroxide, which has antimicrobial properties. An enzyme called invertase converts sucrose into less complex carbohydrates like fructose and glucose. Long chains of starch are broken down into dextrin and maltose when the amylase enzyme is present. The catalase enzyme helps break down hydrogen peroxide into oxygen and water [14].

Table 1. Nutrient composition of honey

Sugars (Range)	Vitamins (mg/100 g)	Minerals (mg/100 g)	Flavonoids	Phenolic acids	Volatile compounds	Other
Erlose (0.5-6.0)	Riboflavin (0.01-0.02)	Potassium (40-3,500)	Luteolin	Caffeic acid	Linalool	Water (15-20)
Glucose (24-40)	Phyllochinon (0.025)	Sodium (1.6-17)	Apigenin	Garlic acid	Octanal	Amino acids and proteins (0.2-0.8)
Fructose (30-45)	Thiamine (0.00-0.01)	Selenium (0.002-0.01)	Kaempferol	Ellagic acid	Furfural	-
Melezitose (-)	Ascorbic acid (2.2-2.5)	Zinc (0.05-2)	Quercetin	Syringic acid	Decanal	-
Others (2.0-8.0)	Niacin (0.01-0.20)	Calcium (3-31)	Chrysin	Ferulic acid	Benzaldehyde	-
-	Folic acid (0.002-0.01)	Phosphorus (2-15)	Genistein	Vanillic acid	Nonanol	-
-	Pantothenic acid (0.02-0.11)	Magnesium (0.7-13)	Pinobanksin	Coumaric acid	Phenylacetaldehyde	-

2. Nutritional content of natural honey

Although honey comprises mainly of sugars and water, numerous other vitamins, minerals, phenolic and amino acids and flavonoids are also a part of it. The presence of all these nutrients in honey account for its health and wellness derived benefits [3]. Table 1 gives the nutrient composition of honey.

3. Some physiochemical compositions of natural honey

3.1 *Viscosity*

Honey's viscosity and other physicochemical qualities are sensitive to a wide range of variables, such as its chemical make-up and temperature. Since viscosity typically decreases with increasing water content, water content is one of the most crucial elements for viscosity [15]. It is crucial to understand this quality because the resulting rheological models may be used to correlate the concentration, temperature, pH, and maturation index of a fluid with its rheological characteristics. This information is crucial for ensuring the quality of equipment and processes across production lines during the intermediate control stage [16].

3.2 *pH*

Hydrogen ion concentration in honey solutions (pH) is measured because it affects the synthesis of compounds like hydroxymethylfurfural (HMF) [17]. Honey's buffer acids and minerals mean that pH analysis, although helpful as a supplementary variable in determining product quality and as a metric for measuring overall acidity, is not directly connected to free acidity [18]. Honey's pH may vary from around 3.5 to about 5.5, depending on the plant it came from, the pH of the nectar, the soil it was grown in, and the amounts of various acids and minerals present, such as calcium, sodium, potassium, and other ash components [19]. Value changes might suggest fermentation or tampering [20]. The honey vesicle is used to convey nectar to the hive, but on the way, the bees may add chemicals from their mandibles to the nectar, which might alter the honey's pH [18].

3.3 *Diastase activity*

Honey includes a wide variety of enzymes, although only in trace amounts; this activity comes from the cooperation of diastase, alpha-glycosidase, peroxidase, lipase, invertase, glucose oxidase, catalase, and acid phosphatase. Honeybees and nectar plants produce these enzymes, and pollen grains contain them in trace amounts [21]. Diastase is a crucial enzyme, and the amount of it in honey varies depending on its place of origin and botanical inspiration. Hydrolyzing the starch molecule is its primary function, and it serves as a quality indicator [22]. The digestion of pollen may need its presence. Denaturing the honey by heating it over its melting point reduces its quality and alters the diastase activity which is intimately linked to the honey's structure [23]. Samples of honey collected at times of rapid nectar flow show signs of lower enzyme levels owing to the buildup of the material processed inside the hive, in addition to shelf life and heating the product.

3.4 *Acidity*

Honey's acidity may occur from the activity of the enzyme glucose oxidase generated in the hypopharyngeal glands of bees, resulting in the production of gluconic acid, which may vary depending on the levels of certain organic acids and inorganic ions like phosphate and the nectar supply. This enzyme is not destroyed by heat or acid during processing; thus, it may continue to impact the honey even after it has been refined and stored [24]. Honey's organic acids only make up around 0.5% of the solids, but they provide a lot of flavor [25].

3.5 *Ash content*

Honey's high ash level is indicative of its high mineral concentration [26]. There are trace quantities of the minerals calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), cadmium (Cd), and zinc (Zn) in the form of sulfate (SO_4^{2-}) and chloride ions (Cl^-) [27]. Honey's color may be affected by the presence of minerals, which are more prevalent in dark honey than in light honey [28]. They change based on the kind of flower used, where it was grown, what kind of bees pollinated it and how it was manipulated [27].

3.6 *Moisture*

One of honey's most distinguishing features is its water content, which impacts its viscosity, specific gravity, maturity, crystallization, taste, preservation, shelf life, and palatability [29]. Several variables, including the kind of bees, the flowers they forage from, the time of year, the amount of maturity the honey has reached in the hive (total dehydration), and the weather, all have a role to play in determining its quality [30]. Honey's stability and lack of fermentation are evaluated based on its moisture content, making this a useful quality criterion. A product's sensory qualities, nutritional attributes, and shelf life may all be adversely impacted by an excess of moisture, which can cause crystallization and encourage the growth of osmophilic microbes responsible for fermentation [31].

3.7 *Electric conductivity*

The capacity of ions in a solution to transport electrons is what gives the solution its electrical conductivity. It correlates with ash level, pH, acidity, minerals, proteins, and other chemicals in honey [32], and it may help identify honey's botanical origin. The conductivity of honey is a useful measure of whether or not it has been altered from its natural state, which is either nectar (with significant variation across species) or honeydew [33].

3.8 *Color*

Honey's price is affected by its color since it is a factor in customer choice that is especially significant on the global market [34]. Honey's color can change depending on a number of factors, including the type of flowers from which it was made, the minerals it contains, how it was stored and processed, the weather conditions during the nectar flow, and the temperature at which it ripened in the hive, the ratio of fructose to glucose and the nitrogen content. Honey produced from the nectars of oak, pine, manuka and chestnut trees are termed dark-colored honey and are also the most frequently utilized for medicinal food purposes [4].

3.9 *Hydroxymethylfurfural (HMF)*

To produce hydroxymethylfurfural (HMF), sugars are dehydrated directly under acidic circumstances, mostly from the breakdown of fructose, which occurs during the heating process of the Maillard reaction [35]. When present in large concentrations, it may be harmful to human health. When present in trace amounts however, HMF is a quality indication in honey that may help tell whether it's been sitting about or just harvested. Concentrations beyond the legal limit may indicate that inverted sugar (syrup) was added during processing, that the product was improperly kept, that it was heated, or that it was contaminated with acidity, water or minerals [14].

3.10 *Optical rotation*

Optical rotation values are known to be an important physical parameter for sugars; these values are based on the attribute that some sugars turn polarized light to the right while others turn it to the left. Optical rotation is a better means than pollen count for distinguishing between blossom honey and honeydew [36]. For honeydew, optical rotation values are always positive while been always negative in negative in blossom honey.

3.11 *Water activity*

Water is an important component of many diets, hence the idea of water activity has been used to examine how water interacts with other dietary components [36]. Honey's microbial activity is hindered by the fact that its water activity is low. Water activity is a metric that affects the amount of water in a meal and how readily it can be used for microbial metabolism. Because of this attribute, the product has greater microbial stability [37], which improves quality, preservation, and shelf life. The water activity measurement is set to 0.0 when there is no water present in the meal and to 1.0 [36] when the sample is made up completely of pure water.

3.12 *Amino acids and proteins*

Amino acids provide the building block for the synthesis of protein and therefore are important components of food. In honey, amino acids come from animals and vegetable sources. Histidine, glycine, proline, alanine, serine, leucine, valine, 4-hydroxyproline, glutamine, arginine etcetera are examples of amino acids contained in honey. Proline is however, the major of the amino acids as all others are present only in trace amounts. The free proline content in honey is important in differentiating genuine from adulterated honey as honey fed with sugar syrup tends to have notably decreased proline values. Honey's proteins too though rare, may be utilized to identify suspected adulterations in commercial goods, along with water content and concentration [38], however its prevalence is little understood. They are also a way to tell when honey has reached peak flavor [39]. Plants and animals both contribute to honey's protein content. The bee's own salivary gland secretions and other materials gathered during nectar collecting and honey ripening make up the animal protein source [40], while nectar and pollen gathered from the wild provide the plant protein source.

3.13 *Total reducing sugars and sucrose*

Honey is mostly water and sugars (which account for 95% of the dry weight). The monosaccharides glucose andHoney is mostly water and sugars (which account for 95% of the dry weight). The monosaccharides glucose and fructose which together account for around 85 percent of the carbohydrates in honey from the *Apis* genus, are called reducing sugars because of their capacity to decrease copper ions in an alkaline solution. Although both fructose and glucose contribute to honey's sweetness, fructose's strong hygroscopicity makes it more palatable, while glucose's weak solubility has a tendency to affect crystallization [41]. Fructose is the most common form of sugar in honey because it affects the honey's ability to crystallize, making liquid honey more stable. Succrose and maltose, two disaccharides, make up 10% of the sugars in honey [42]. In general, honey from the *Apis* genus contains between 2% and 3% sucrose. Honey with a relative humidity exceeding 20% [43] is likely to be tainted or collected prematurely.

4. Microbiology of honey

Honey is a thick, sweet, flavor-like foodstuff obtained from nectar or juice produced by bees [44]. Honey can be gotten from different regions of plants and trees in different parts of the world. The low pH and high sugar content of concentrated honey makes it difficult for the proliferation of microbes [43]. The bacteriostatic qualities inherent in honey control the growth and survival of a host of microorganisms thus making the microbial count of honey quite low compared to most other liquids [44]. Some microorganisms have the ability to withstand high osmotic pressure, acidity and antimicrobials found in honey. Examples of these microbes include yeast, mould and spore forming bacteria [37]. The pollen and nectar, production area, production plants, and storage containers that are contaminated are the primary vectors for the bacteria that cause problems with honey [45]. Researchers have found that bees' digestive systems are home to 1% yeast, 27% Gram-Positive bacteria like *Bacillus*, *Streptococcus*, and *Clostridium spp*., and 70% Gram-Negative bacteria like *Achromobacter* [45], *Citrobacter*, *Enterobacter*, *Erwinia*, *Escherichia coli*, *Flavobacterium*, *Klebsiella*, *Proteus*, and *Pseudomonas*. Equipment, poor hygiene practices during handling and polluted soils are other post-harvest agricultural factors that might introduce microorganisms [46].

The presence of pathogenic microorganisms in honey which cause infections have been reported [47]. Spores of *Clostridium botulinum* have been reported by some researchers to be implicated in honey [16]. Honey to be used as additive for infant formulas for infants less than 12 months must be given heat treatment to eliminate *botulinum* spores [48]. The presence of microorganisms or their spores in honey can lead to a reduction in quality, enzymatic degradation as well as generation of mycotoxins and possibly health problems [31]. These microorganisms can also directly affect the shelf life and the hygienic quality of honey [45]. It is therefore imperative to determine the microbiological content of commercial honeys irrespective of their status as food ingredients and not a staple food.

Honey, particularly samples which have relatively high moisture content and water activity, are perfect habitats for osmotolerant yeasts that may produce blocked fermentations [16]. Diluted honey samples have been shown to promote the development of non-pathogenic bacterial strains and destroy killer pathogens, according to a number of studies [49].

Depending on its source, honey may be antimicrobial due to its low pH, capacity to create hydrogen peroxide, and the presence of components such glucose oxidase, flavonoids, phenolic compounds, etc [16]. Its antibacterial activity significantly inhibits the growth of molds and yeasts [46]. Keep in mind that yeast and bacteria have a direct relationship to the honey's storage temperature for instance, experiments in which different bacterial strains were aseptically inoculated into honey at a constant temperature of 20 °C showed that the viability of the bacterium strains was lost between 8 and 24 days after inoculation. Even 16 weeks later, there was no discernible change in the spore count.

Honey spoilage could result from fermentative metabolites produced by yeast and acetic acid produced by acetic acid bacteria [50]. The quality of honey could also be affected by the time and prevailing conditions of storage as well as the level of hygiene that is observed during harvest and extraction [44]. The impact of microorganisms implicated in honey has also affected its application as food for infants, treatment of wounds, cancers and dental issues [51].

Table 2 below shows some of the microorganisms implicated in honey as revealed by several researchers.

4.1 *Antimicrobial activity of honey*

The antibacterial effect of honey is thought to work via a different mechanism than antibiotics, which either kills the bacteria directly or interferes with their ability to use energy inside the cell. Honey's antibacterial action is linked to four different characteristics. Dehydration of germs by pulling moisture out of the air, slowing the development of germs helped by its high sugar content [52]. Having an acidic pH range (3.2-4.5) that is sufficient to prevent the development of most germs and possessing glucose oxidase, which generates hydrogen peroxide, this been the most essential antibacterial component. However, there are writers who argue that the nonperoxide action is more crucial [53]. Honey has also been shown to include a number of phytochemical components that contribute to its antibacterial effect [54].

Antibacterial components that include peroxides are hydrogen peroxide, glucose oxidase, catalase, and phytochemicals [47]. Furthermore, honey's antibacterial characteristics are due in large part to the presence of volatiles, organic acids, lysozyme, beeswax, nectar, pollen, and propolis [55]. Small amounts of oligosaccharides may also be found in honey. Some other research have found ([56] a correlation between the sugar content of honey and the growth inhibition of certain intestinal bacteria [57]). It has been further suggested that plant-derived ingredients are responsible for some of the antibacterial action. Honey's physical and chemical qualities too make it stand out in wound dressing, allowing it to clear infections quickly, speedily debride, control inflammation, reduce scarring to a minimum and stimulate angiogenesis, tissue granulation, and epithelial formation [58].

4.1.1 *Antiviral activity of honey*

Infections and lesions caused by viruses are often brought about by either naturally occurring or ubiquitous triggers [57]. The results of recent research have shown that honey may have antiviral properties. Several of honey's components including copper, a trace metal that inactivates viruses are responsible for its antiviral properties and have been shown to be effective in the management of lesions. Honey's ascorbic acid, flavonoids, and H_2O_2 synthesis similarly impede viral development by preventing viral transcription and translation [55]. Evidence from *in vitro* research indicates that honey may inhibit the growth of several viruses, including those responsible for the spread of herpes simplex and zoster [59]. Honey is composed of saliva and pharyngeal gland secretions from honeybees. There have been recent discoveries of nitrite and nitrate, two metabolites of nitric oxide (NO), in the salivary gland [59]. The energy molecule NO is known to induce host defense against viruses, including DNA and RNA. In addition to stopping viral replication, NO also inhibits the growth of viral lesions [59]. NO inhibits replication by blocking the production of viral proteins such polymerase, nucleic acid, and capsid. Studies have also shown that the flavonoid component of honey may prevent viral proliferation and transcription [60].

4.1.2 *Antifungal infections*

It has been shown that honey may prevent the growth of fungus as the substance both in its pure and diluted forms has exhibited antifungal and antitoxin effects. *Aspergillus niger*, *Aspergillus flavus*, *Penicillium chrysogenum*, *Microsporum gypseum*, *Candida albicans*, *Saccharomyces*, and *Malassezia species* are all killed by it according to studies [54]. Honey has also been reported to be effective against cutaneous and superficial mycoses including ringworm and athletes' foot. Honey's high sugar content, glucose oxidase, and methylglyoxal all contribute to its possible antimicrobial impact [61]. The exact process is still unclear, but researchers have proposed a few possible explanations.

Since honey prevents biofilm development, disrupts already-established biofilms, and induces changes to the exopolysaccharide structure, it acts as an antifungal agent. It's disruption of the integrity of cell membranes leads to a reduction in biofilm cell surface area and ultimately, cell death or growth inhibition [55]. Using an atomic force microscope, researchers found that honey effectively removed all traces of biofilm after halving the thickness of the exopolysaccharide layer [57]. Scientists also discovered that the flavonoid component of honey slows the development of fungus, alters their outer shape and membrane integrity, and suppresses several cellular processes involved in germ tube formation. Poor membrane growth is linked to the suppression of germ-tube development. The proportion of cells in the G0/G1 phase and/or the G2/M phase have also been observed to be decreased by honey's flavonoid extract which influences hyphal transition [55].

4.1.3 *Sensitivity of pathogens to honey*

Research shows that honey inhibits the growth of over 60 different bacterial species, including both aerobic and anaerobic, gram-positive and -negative strains [62]. Several studies have also indicated that the viscous substance is effective against a wide range of bacteria, including *Bacillus anthracis*, *Corynebacterium diphtheriae*, *Haemophilus influenzae*, *Klebsiella pneumoniae*, *Listeria monocytogenes*, *Mycobacterium tuberculosis*, *Pasteurella multicoda*, *Yersinia enterocolitica*, *Proteus species*, *Pseudomonas aeruginosa* [59]. Natural honey displayed an antibacterial action against the community-associated methicillin-resistant *Staphylococcus aureus* (MRSA) germs in *in-vitro* condition, according to a limited number of case studies [63]. Researchers showed that honey had a MIC (minimum inhibitory concentration) against bacteria ranging from 1.8% to 10.8% (v/v), meaning that it was effective against bacteria even after being diluted nine times, and up to 56 times against *Staphylococcus* aureus, the most prevalent wound infection agent [64]. Some bacteria responsible for urinary tract infections (UTIs), such as *E. coli*, *Proteus species*, and *Streptococcus faecalis*, have been also been shown to be susceptible to the antibacterial action of honey, leading to claims that honey when diluted appropriately may cure UTIs.

The gastritis-causing *H. pylori* isolate was demonstrated to be suppressed by a 20% honey solution in *in vitro* tests. Isolates that showed resistance to other antimicrobials nevertheless responded to this treatment [65]. Honey unlike most traditional antibiotics, reportedly does not promote the growth of antibiotic-resistant bacteria and may be used indefinitely [59].

Depending on the concentration, honey has bacteriostatic and bactericidal effects. Bacteriostatic activity was attained at concentrations of 5%-11% (v/v) in both pasture honey and manuka honey, whereas bactericidal activity was achieved at concentrations of 8%-15% in both. Instead of killing bacteria, fake honey (a sugar solution that mimics honey's composition) only slowed their growth by 20% to 30% [66].

4.2 *Applications of honey in wound dressing*

When honey is applied to a wound, it speeds up the healing process and gets rid of any infection that may have been there. The situation is analogous with burns. A honey dressing may hasten the healing process, disinfect the wound, and ease the discomfort [67]. Both the osmotic outflow and the bioactive impact of honey contribute to the remarkable speed with which it disinfects wounds. Honey's respiratory burst to create hydrogen peroxide and stimulate macrophage antibacterial activity requires glucose supplied by the enzyme glucose oxidase [68]. The direct nutritional influence of a variety of amino acids, vitamins, and trace minerals present in honey on repairing tissues is also important. When honey is put on a wound, the osmotic outflow helps to flush away dirt and other particles lying at the wound's base making the dressing non sticky so that it may be removed without any discomfort. But despite this, some people have still felt actual pain or distress and a possible explanation for this been that the acidity of honey irritates exposed nerve terminals [52]. However, the antimicrobial effects of honey may not be the only reason it helps wounds heal for recent studies have shown that honey, even at concentrations as low as 0.1%, may activate phagocytes and increase the growth of B- and T-lymphocytes in cell culture from peripheral blood [69]. One research even found that natural honey dramatically boosted the production of immune-activating cytokines such tumor necrosis factor-α (TNF-α), interleukin (IL)-1β, and IL-6 from MonoMac-6 cells (human monocytes). Because of this, it was hypothesized that honey's wound-healing properties may stem from its ability to activate monocytic cells, which then release inflammatory cytokines [70]. Other benefits provided by honey dressing may be financial as the costs associated with hospital stays, bandages, and surgeries are minimized when patients recover quickly [71].

Studies comparing honey dressing for burns to amniotic membrane treatment, silver sulfadiazine dressing, and boiling potato peel dressing have also been undertaken. Early healing with a reduced degree of contracture and scarring was seen in instances treated with honey dressing [72]. It has also been shown that skin grafts treated with honey show good histological preservation. Using natural honey for the treatment of radiation-induced mucositis has been shown to be successful, as described by [73]. In a surprising turn of events, honey was formerly used to diagnose measles in its earliest stages. Massages with honey are said to make measles eruptions worse the day after they are applied but the honey is applied repeatedly until the rash clears up completely [74].

4.2.1 *Applications of honey for wound healing*

Wound healing is one of the most well-researched and beneficial applications of honey [58]. During World War I, the Russians found that using honey on wounds helped keep them from becoming infected and sped up the healing process. In order to heal wounds such as ulcers, burns, fistulas, and boils, the Germans also used a combination of cod liver oil and honey [75]. Honey has been shown to be effective in the treatment of a wide variety of wounds, including those caused by: abrasions, abscesses, amputations, bed sores/decubitus ulcers, burns, chill blains, burst abdominal wounds, cracked nipples, fistulas, diabetes, malignancy, leprosy, trauma, cervical, varicose, sickle cell, and septicemia. There are several overlapping processes at work during normal wound healing, such as coagulation, inflammation, cell proliferation, tissue remodeling, and replacement of injured tissue [76]. Wound healing is aided by honey because it helps get rid of necrotic tissue during the inflammatory phase, speeds up the remodeling phase, and slows down the bacterial growth phase [52]. In laparoscopic oncological surgery, it has been utilized to prevent tumors from implanting themselves in wounds. Honey has been used to treat open wounds without reports of infection. And has been a possible therapeutic use in the management of gingivitis and periodontal disease [77]. A young boy's knee amputation wound, infected with *Pseudomonas* and *Staphlococcus*. *aureus* and that was resistant to standard therapy, healed completely in ten weeks after being dressed with sterilized active manuka honey dressing pads [78]. Recent research on Fournier's gangrene has shown encouraging results, including a quick reduction in edema and discharge, a speedy recovery with little scarring, successful wound debridement, and a lower risk of death [79].

Research published recently showed that honey promotes wound healing in IL-6-deficient mice by increasing IL-6 and TNF- production at the wound site [80]. The healing process is sped up by the cytokines and interleukins (cytokines) that are released by honey-stimulated lymphocytes, phagocytes, monocytes, and/or macrophages. These include TNF-alpha, IL-1beta, and IL-6 [81]. Honey's osmolarity and high sugar content also aid in the healing process for instance, if the blood circulation at the wound site is adequate, honey's osmotic impact will drive water out of the wound bed by a straightforward outflow of lymph [46]. By stimulating production of AMPK (5' adenosine monophosphate-activated protein kinase) and antioxidant enzymes, which reduce oxidative stress also, honey has been proven to speed up the healing process after an injury. Endogenous antioxidants are produced by the body, and exogenous antioxidants are also useful. There are two types of endogenous antioxidants: those that rely on enzymes and those that don't. Superoxide dismutase, catalase, and glutathione peroxidase are all examples of enzymatic antioxidants (GPx). Exogenous antioxidants include several micronutrients, whereas endogenous antioxidants consist of vitamins E and C, glutathione (GSH), and some small molecules [82]. These antioxidants all aid in healing by promoting mitochondrial activity and the proliferation and migration of human dermal fibroblasts [82].

The presence of serine proteases and matrix metalloproteases near injury sites is another way by which protein degradation is facilitated. Some inhibitors prevent these protease enzymes from functioning normally. Once the inhibitors are rendered ineffective by H_2O_2, the proteases may do their work. As a result, H_2O_2 acts as a physiological switching stimulus, activating and deactivating these enzymes by oxidation, respectively. Honey has been shown to increase H_2O_2 production, according to studies. Proteases that are already functioning in the body break down the debris and germs in the wound and the osmotic outflow and active action from honey make quick work of clearing away this trash. Moreover, H_2O_2 promotes the development of repair cells like fibroblasts and epithelial cells during inflammation. H_2O_2 also promotes cell proliferation and wound healing by activating nuclear transcription factors (NTFs) [82].

H_2O_2 activates insulin receptor complexes, which in turn sets off a cascade of molecular processes in the cell, as elaborated by several additional mechanisms. As a consequence, amino acids and glucose may be taken in more easily, promoting cellular development. It's possible that the vitamins, minerals, carbohydrates, and amino acids in honey are what fuel the developing cells. As a result, phagocytes are better able to consume invading bacteria by using glucose as fuel. Honey promotes tissue regeneration via increasing monocyte and lymphocyte proliferation, both of which are influenced by cytokines. Increased inflammation is triggered when mitogen or honey-activated monocytes produce reactive oxygen species. As a result, the capillaries in the area get constricted and the surrounding tissue swells. As a consequence, the cells get less oxygen and nutrition. Over time, it stunts tissue regeneration and wound healing [44].

5. Some health and other benefits of honey

5.1 *Antidiabetic activity of honey*

Type 2 diabetes mellitus is a metabolic condition with several interrelated components. The lack of insulin or malfunctioning insulin is to blame [63]. Several abnormalities in lipoprotein and carbohydrate metabolism contribute to the increased glucose level seen in this condition [83]. Hyperosmolar, diabetic ketoacidosis, and a hyperglycemic condition are all possible acute consequences of this illness [84].

Research in both animal models and human clinical trials has shown that honey has antidiabetic benefits [47]. And so has been pointed to as a possible anti-diabetic drug [70]. In streptozotocin-induced diabetic rats [85], the antioxidant action of honey was enhanced at dosages of 0.2, 1.2, and 2.4 g/kg/day. Similar results were shown when honey at a 60% (W/V) [44] concentration was inhaled for the treatment of type 2 diabetes mellitus. Honey's fructose content explains why it lowers blood sugar levels, making it a useful treatment for diabetes. Fructose aids in regulating the insulin-response system which in turn, leads to a steady blood sugar level. One other explanation for the drop in blood sugar is that the oligosaccharide palatinose, a kind of sucrose, delays digestion and absorption. Patients with diabetes saw their condition improve as a consequence of this [86]. Captivation of glucose in cells has also been shown to be enhanced when working in tandem with fructose [87], which may lead to reduced food-intake or absorption and a corresponding hypoglycemic impact. Carbohydrates are absorbed into the body after being hydrolyzed into monosaccharides such glucose, fructose, and galactose [69]. A protein- and energy-mediated diffusion mechanism has been proposed [46] for fructose uptake by the two receptors GLUT5 and/or GLUT2. Glucose and fructose both boost GLUT2 mRNA expression. However, only fructose causes an increase in the production of GLUT5 mRNA, leading to rapid absorption of fructose [88, 89]. Fructose also exhibits a unique hypoglycemic effect in the liver, allowing it to control glucose levels. In this mechanism of action, fructose promotes hepatic glucose phosphorylation [90] by activating phosphorylation enzymes like glucokinase. Glycogenolysis is slowed or stopped when these enzymes are blocked. Fructose's crucial regulatory function in hyperglycemia regulation is shown by the fact that it controls the whole glycogen and glucose metabolism [91].

Modulation of the insulin signaling pathway is another potential mechanism by which honey exerts its hypoglycemic impact [92]. The PI3K/Akt pathway is essential for proper insulin signaling. Cell cycle progression, cell survival, and cellular proliferation are all regulated by its substrates, and this protein is well-known for its modulatory roles in these processes. Recently, in hyperglycemic conditions, researchers looked at how honey extracts affected the Akt-activated insulin signaling pathway in pancreatic cells. Increased NF-kappa B, mitogen-activated protein kinase, and insulin receptor substrate 1 (IRS-1) serine phosphorylation were reported in individuals with developing insulin resistance. Severe decreases in both Akt expression and insulin content were observed. Honey and quercetin extract were shown to reduce insulin resistance and increase insulin levels in this research. The expression of Akt was enhanced by honey treatment, but IRS-1 serine phosphorylation, nuclear factor-kappa B, and mitogen-activated protein kinase expression were decreased [90].

It has additionally been shown that honey supplementation may moderate oxidative stress and hyperglycemia. Its anti-diabetic effects as an antioxidant are widely documented [93]. The levels of triglycerides, hepatic transaminases, glycosylated hemoglobin (HbA1c), and HDL cholesterol are all improved, and other metabolic abnormalities associated with diabetes are either decreased or eliminated [65].

5.2 *Anticardiovascular disease activity of honey*

Blood glucose, cholesterol, C-reactive protein (CRP), and body weight are all cardiovascular risk factors that honey may help control [82]. Drug treatment, particularly anti-arrhythmic medications, may be lifesaving in the management of cardiovascular disorders. However, the risks associated with anti-arrhythmic medicines (including potentially fatal arrhythmias in certain patients) have resulted in restrictions on their use [94]. As a result, there is a push to provide medications that have fewer side effects without sacrificing effectiveness. Historically [95], people have utilized honey for its therapeutic properties. However, much of the research done on honey's benefits against cardiovascular risk factors including hyperlipidemia and free radical generation has been conducted on animals [96]. Honey's possible function in reducing cardiovascular risks may be due to its content of glucose, fructose, and trace minerals like copper and zinc. Low-density lipoprotein (LDL), high-density lipoprotein cholesterol (HDL-C), triacylglycerole, body fat, glucose, and cholesterol levels are all lowered in human subjects that take honey 70 g for 30 days. This effect is shown in both cardiac patients and healthy human subjects. Honey contains several antioxidants, including vitamin C, monophenolics, flavonoids, and polyphenols. The risk of cardiovascular disease is inversely proportional to the consumption of flavonoids on a regular basis; it also contains many different phenolic chemicals, some of which have been shown to have a positive impact in the treatment of cardiovascular disorders. The preventive benefits of phenolic compounds in coronary heart disease (CHD) primarily comprise antithrombotic, anti-ischemic, antioxidant, and vasorelaxant actions. Flavonoids have been hypothesized to reduce the incidence of CHD via three main mechanisms namely; enhanced coronary vasodilatation, reduced blood clotting due to impaired platelet function, and protection against LDL oxidation [70]. The effects of natural honey on total cholesterol, low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, triacylglycerole, C-reactive protein (CRP), fasting blood glucose, and body weight were studied in 38 obese people. Total cholesterol, LDL-C, triacylglycerole, and CRP levels were all shown to be lower among those who consumed 70 grams of natural honey daily for 30 days. Furthermore, the authors found natural honey to lowers cardiovascular risk factors, especially in people with increased risk factors, and also to suppress weight gain in subjects who are already overweight or obese [97]. Humans were put through a series of tests comparing the effects of consuming 75 grams of real honey to the same quantity of manufactured honey (fructose + glucose). The spikes in insulin and CRP after consuming glucose were much larger than those after consuming honey. Moreover, honey lowered total cholesterol, LDL-C, and TG while marginally increasing HDL-C. Those with hypertriglyceridemia saw a rise in their TG levels when given imitation honey, whereas those given real honey saw a drop. Synthetic honey was associated with a rise in LDL-C in hyperlipidemic individuals, whereas honey was associated with a reduction. While both honey and dextrose raised plasma glucose levels, honey had a far smaller effect on diabetic individuals. To add to that, nitric oxide (NO) metabolites may be found in honey, and research suggests that NO content may provide protection against cardiovascular disease [98]. Some of nitric oxide's cardioprotective actions include controlling blood pressure and vascular tone, blocking platelet aggregation and leukocyte adhesion, and stopping the proliferation of smooth muscle cells [59]. When NO levels rise, blood arteries relax and widen. Multiple stimuli, including acetylcholine, shear stress, and cytokines, trigger its production of endothelial nitric oxide synthase (eNOS). Several proteins are also phosphorylated in response to NO, leading to smooth muscle relaxation. Renal regulation of extracellular fluid balance is dependent on nitric oxide's (NO) vasodilatory function, which is also essential for the control of blood pressure and blood flow. Honey's flavonoids have been studied for their potential to reduce oxidative stress and boost nitric oxide (NO) bioavailability, two mechanisms through which honey may moderate cardiovascular risks. Just as nitric oxide (NO) generation is boosted by rutin, eNOS gene expression and activity are also increased by rutin. Intercellular adhesion molecule-1 (ICAM-1) expression on endothelial cells is reduced by naringin in response to hypercholesterolemia. Catechin and quercetin, two of the most abundant flavonoids in honey, have recently been demonstrated to limit the growth of aortic atherosclerotic lesions and the atherogenic alteration of LDL [3].

Honey lowered venous blood pressure, which in turn lowered cardiac preload and alleviated venous congestion [99]. Short-term perfusion of enriched Krebs solution with natural honey for 10 minutes before and 10 minutes after ischemia was perfused in isolated rat hearts by [100] showed protective effects of natural honey as a pharmacologic preconditioning agent against ischemia/reperfusion (I/R) induced injuries [101]. Another *in vitro* investigation found that 45 days of chronic oral treatment of natural honey had powerful anti-arrhythmic and anti-infarction benefits in rats [102]. Researchers found that giving normal or stressed rats natural honey (5 g/kg) for 1 hour prior to an injection of adrenaline (100 mcg/kg) prevented epinephrine-induced vasomotor dysfunction and cardiac abnormalities and maintained the favorable inotropic effect of adrenaline. The authors concluded that the cardioprotective and therapeutic effects of natural honey against adrenaline-induced cardiac and vasomotor dysfunction could be caused either directly (via its high total antioxidant capacity and enzymatic and non-enzymatic antioxidants, in addition to its substantial quantities of mineral elements such as magnesium, sodium, and chlorine) or indirectly (via the influence of vitamin C on the release of nitric oxide from endothelium) [15]. Superoxide dismutase, glutathione peroxidase, and glutathione reductase, together with creatine kinase-MB, lactate dehydrogenase, aspartate transaminase, and alanine transaminase, were observed to be restored to pretreatment levels after isoproterenol-induced myocardial infarction in Wistar rats. This demonstrates that honey provides protection against the deleterious effects induced by free radicals that are known to be fatal. Honey has also been demonstrated to decrease cardiac troponin I (cTnI), triglycerides (TG), total cholesterol (TC), and lipid peroxidation (LPO) products in a rat model of myocardial infarction [62].

5.3 *Antigastrointestinal tract disease activity of honey*

The use of honey for the prevention and treatment of bacterial and rotavirus-caused gastrointestinal infections such gastritis, duodenitis, and gastric ulcers after oral administration has been documented [103]. The first step in the progression of a bacterial infection of the gastrointestinal tract is the attachment of bacteria to mucosal epithelial cells lining the gastrointestinal system. One method for preventing illness is to prevent harmful germs from attaching to the intestinal epithelium. Honey's ability to inhibit bacterial adhesion was shown to be independent of its impact on epithelial cells, as shown by [44]. This ability may rather be attributed to a number of factors, including: Some of the fractions inside honey may affect the electrostatic charge or hydrophobicity of bacteria, both of which have been documented to be essential variables in the interaction of bacteria with host cells.

Honey has been discovered to be an effective treatment for diarrhea and gastroenteritis [104], for when used in replacement fluid at a concentration of 5% (v/v), it was shown to be effective in reducing the length of diarrhea in instances of bacterial gastroenteritis. Honey also improves rehydration fluid by boosting potassium and water intake while decreasing salt intake, acts as an anti-inflammatory agent, aids in the healing of injured intestinal mucosa, and promotes the development of new tissue [22]. Oral pretreatment with honey (2 g/kg) reduced gastric indomethacin-induced lesions, microvascular permeability, and myeloperoxidase activity, as shown by [105]. Honey's antibacterial activity is around average, making it effective against *H. Pylori* owing to the presence of hydrogen peroxide at a concentration of 20%.

The extent of the lesions induced by ethanol was significantly reduced after perfusion of the stomach with isotonic honey to test the cytoprotective capabilities of natural honey [106]. Natural honey may also be used in place of sucralfate in the treatment of peptic ulcer disease, since it has been shown to have curative effects for the recovery of antral ulcers [107].

5.4 *Antioxidant activity of honey*

We now know that radicals change molecules and change genes in many different kinds of organisms. In fact, oxidative stress has been linked to 86 different illnesses. Antioxidants are substances that prevent further damage from occurring due to free radicals in lipid bilayers and membranes. Many long-lasting, chronic, and degenerative diseases including cancer, aging, atherosclerosis, and mutagen synthesis - are vulnerable to oxidative stress [108]. Against oxidative stress, cells have developed defensive mechanisms the body also to combat free radicals, produces antioxidants such vitamin C, vitamin E, and polyphenols [109]. Other protective agents include catalase, superoxide dismutase, peroxidase, ascorbic acid, and tocopherol. Sugars, proteins, fats, and nucleic acids all benefit from the stimulation provided by these antioxidants. This stimulation leads to cellular changes that eventually trigger an antioxidant response [110]. There is significant antioxidant action in honey. Apigenin, pinocembrin, kaempferol, quercetin, galangin, chrysin, and hesperetin are only some of the flavonoides found in honey, along with phenolic acids like ellagic acid, caffeic acid, p-coumaric acid, and ferulic acid, vitamin C, tocopherols, catalase, superoxide dismutase, reduced glutathione. A synergistic antioxidant action is produced by the majority of the chemicals listed. Because of its antioxidant properties, honey has been proposed as a safe and effective substitute for artificial preservatives such sodium tripolyphosphate in food storage [111].

Most of honey's antioxidant activity is determined by its plant origin, whereas the rest is only somewhat influenced by its processing, handling, and storage conditions [59]. Also strongly linked with antioxidant activity is total phenolic content of a plant for instance, the overall phenolic content of black honey is greater and hence its antioxidant activity, according to a number of studies. Additionally, a robust relationship was discovered between the hue of honey and its antioxidant power. Honey's flavonoids may be able to access different parts of the human body and elicit diverse physiological effects, as shown by the fact that antioxidant activity was found in both the ether and water fractions [112]. These antioxidant qualities of honey may be quantified by testing its ability to scavenge free radicals using assays including the oxygen radical absorbance capacity (ORAC) assay, the 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging assay, and the ferric reducing antioxidant power (FRAP) assay. High antioxidant capabilities have been found in honey from a wide variety of floral origins and regions [113]. The presence of phenolic acids and flavonoids in honey are thought to be the source of its antioxidant capacity. Sugars, proteins, amino acids, carotenoids, organic acids, Maillard reaction products, reactive oxygen species (ROS), and other minor components all contribute to the antioxidant effect [59]. Honey (1.2 g/kg) was shown to increase beta-carotene, vitamin C, glutathione reductase, uric acid levels and so, antioxidant activity in healthy adult volunteers [114]. There is debate about the precise antioxidant mechanism; however some of the hypothesized processes include free radical sequestration, hydrogen donation, metallic ion chelation, flavonoids' substrate action for hydroxyl, and superoxide radical activities.

5.5 *Anti-inflammatory activity of honey*

When vascular tissues are exposed to harmful stimuli, they respond with a complicated biological process known as inflammation. It's a protective mechanism that the body employs to get rid of whatever infections or stimuli caused the harm. Inflammation may be either acute or persistent. Acute inflammation occurs quickly after a stimulus has entered the body and manifests clinically as redness, discomfort, itching, and functional impairment [115]. When acute inflammation is not properly addressed in a timely manner, it might progress into chronic inflammation. Many chronic illnesses and disorders point to this as a primary contributor. Consequently, liver disorders [116], renal diseases [117], and cancer [59] are thought to be combated by anti-inflammatory activity. Cytokines, cyclooxygenases (COXs), lipoxygenases (LOXs), mitogens, macrophages, tumor necrosis factor (TNF) factors, and many other elements of inflammatory pathways may all play a role in the initiation of an inflammatory response.

It is widely established that honey has anti-inflammatory effects. Studies on many organisms ranging from cell cultures to animal models and to humans have all shown it to possess anti-inflammatory properties [118]. Honey varieties that are rich in polyphenols (chestnut, oak and etcetera) tend to have high anti-hyaluronidase activity (hyaluronidase enzyme degrades high molecular weight hyaluronic acid thus limiting its anti-inflammatory actions) thus allowing the acid more time to carry out anti-inflammatory activities. Against hyaluronidase-induced anti-inflammatory failures too, these honey varieties exhibit high protective and complementary potential [119]. Furthermore, pathways involving mitogen-activated protein kinase (MAPK) and nuclear factor kappa B (NF-B) are two examples of the inflammatory pathways that become active in disease [75]. Several additional inflammatory mediators, enzymes, cytokines, proteins, and genes are induced after MAPK and NF-B activation, including cyclooxygenase-2 (COX-2), lipoxygenase-2 (LOX-2), C-reactive protein (CRP), interleukins (IL-1, IL-6, and IL-10) and tumor necrosis factor alpha (TNFα are also usually present. Inflammation and angiogenesis are both linked to the etiology of illness, and all these indicators of proinflammatory activity are thought to play a significant part in the process. Recent in vivo investigations have proven that honey's anti-inflammatory properties work as edema and plasma levels of inflammatory cytokines such IL-6, TNF, PGE2, NO, iNOS, and COX-2 were shown to be reduced by honey in these investigations. In addition, it has been shown that honey inhibits the degradation of the protein IB (inhibitor of kappa B) and reduces nuclear translocation of NF-B [46]. Proinflammatory enzymes including cyclooxygenase-2 (COX-2), prostaglandins [120], and inducible nitric oxide synthase (iNOs) [121] have been shown to be inhibited by phenolic acids and flavonoids such chrysin, quercetin, and galangin. Further studies have revealed that the flavonoid concentration of honey reduces the development of MMP-9 (matrix metalloproteinase 9), an inflammatory mediator responsible for chronic inflammation.

In addition, evidence suggests that macrophages, monocytes, and neutrophils create reactive oxygen species that promote inflammation. To counteract inflammation, honey prevents the release of these cells. It does this by preventing the formation of keratinocytes and leukocytes. Honey's H_2O_2 generation during an inflammatory reaction has been also shown to encourage the development of repair cells like fibroblasts and epithelial cells thus, honey's anti-inflammatory properties set it apart as a potential new agent for disease modulation [122].

Furthermore, inflammation is linked to abnormalities in arachidonic acid metabolism. Arachidonic acid is converted into leukotrienes through the LOX pathway (LTs). The LOX isozymes come in three different forms: 12-LOX, 15-LOX, and 5-LOX. When activated, 12-LOX may cause inflammatory/allergic problems, whereas 15-LOX can produce 15-HETE have anti-inflammatory properties, and 5-LOX can produce 5-HETE, as well as LTs. It has been shown that several polyphenols in honey may inhibit LOXs [123]. Honey's phenolic components and flavonoids are responsible for its anti-inflammatory activity [122].

5.6 *The use of honey as a preservative*

Food spoilage is defined as a microbiological, chemical, or physical alteration in food which makes it undesirable and unacceptable to consumers. Food spoilage is mainly caused by the activities of microorganisms [124]. Food preservation involves the application of food processing practices which hinders the proliferation of microorganisms and retards the oxidation of fats that cause rancidity [63]. It is imperative that the activities of these organisms be checked in foods using a hurdle approach which should involve the use of natural food additives like honey as a food preservative [125].

The antimicrobials and antioxidants present in honey promote its function as a food preservative. Honey functions as a food preservative based on its high sugar concentration which tends to "squeeze" the water out of microbial cells that could be responsible for spoilage of the food. This process causes a drying up of the cells ultimately leading to their death [126]. Some of the properties of honey which help to prevent the proliferation of microorganisms in foods include high sugar concentration, low pH value, glucose oxidase and bee defensin-1 [53]. The presence of antioxidants and phytochemicals like phenols, hydrogen peroxide, flavonones, and carotenes also inhibits the proliferation of bacteria like *Listeria*, *Monocytogenes*, *Staphylococcus aureus* etc. Bioactive compounds present in honey which work in synergy to produce their antioxidant effect include flavonoids, phenolic acids, tocopherols, catalase, superoxide dismutase, glutathione, ascorbic acid, and peptides [127].

The detection of minute amounts of *Clostridium botulinum* in honey has been reported to enhance its use as a food preservative since the bacterium provides a natural source of antioxidants and has been used to ameliorate the negative effects of browning in fruits and vegetable processing caused by polyphenol oxidase [46].

The antioxidant activities of honey are correlated to its use in foods as a sweetening agent as it helps protect consumers from tissue damage caused by free radicals and oxidative compounds [128]. The antimicrobial characteristics of honey have been linked to peptides, glycopeptides and oligosaccharides present in honey. The glucose oxidase of honey supplies a regular amount of hydrogen peroxide (H_2O_2) at concentrations which enhances antibacterial function, but which will not cause damage to the tissues of the body. It has been reported that honey has a preservative effect on prolonging the shelf-life of fruits and vegetables such as strawberries and tomatoes without the assistance of chemical preservatives. According to the study, the fruits appeared much more appealing to consumers and was recommended to farmers as a better preservative tool especially as it better suited to consumers allergic to chemicals [129].

5.7 *The utilization of honey for food*

Honey is consumed fresh in most cases either in the liquid form or semi-solid processed form. Consumption of 100 g of honey provides the body with nearly 320 kcal [63]. The benefits accrued with the intake of honey as food has been verified by several researchers. Consumption could be either for medicinal purposes, as food or as additives in several food systems [126]. In the food industry, it is common for honey to be produced in large quantities either for consumption by itself or in combination with other local products before consumption. For example, in the production of dairy products like yoghurts where honey is used as a sweetener so as to extend the shelf-life of the product for reasonably longer periods [86]. Honey is sometimes used as flavoring additive in the manufacture of gum products. It has been reported that honey has been utilized in the manufacture of non-alcoholic drinks like fruit juices in Japan where it is employed as a flavoring agent and sweetener [130].

In addendum, the addition of honey to infant formulas and its use as a flavoring agent have not only gained worldwide recognition but also improved the nutritional status of the food products [131]. Honey is easily digestible and is a rich source of energy to the body it also contains all the classes of food in their correct proportion with glucose and fructose forming a bulk of the carbohydrate fraction [132]. The amount and type of proteins contained in honey can be attributed to the origin of the honeybee. Vitamins present include the B complex vitamins and ascorbic acid. Honey also contains trace minerals like Calcium, Iron, Copper, Manganese, Phosphorus, Potassium, and Zinc [133]. The nutritional status of honey posits it as an ideal candidate for food for humans of all age grades. Honey consumed as food helps boost energy, enhances physiological processes like growth and promotes health maintenance regimes like exercises and sporting activities [134]. It has been reported by several researchers that consumption of honey could help in weight gain due to facilitated bone mass increase and impregnation with minerals [135]. It has also been reported that consumption of honey has an effect on the enhancement of gastrointestinal function. The use of honey in making sweets and candies for children could be more beneficial instead of the artificial sweeteners that are commonly used which is detrimental to the health of the children. This submission has been supported by several researchers who revealed the use of honey in palliating the extreme consequences of neonatal diarrhea and gastroenteritis [136].

6. The socio-economic importance of honey

The socio-economic importance of honey to human development and industrial output cannot be overemphasized. This is because honey plays a vital role in balancing human nutrition as a better option to sugar, and as a natural input to most industrial products in Nigeria, Africa and the world at large. In Africa the harvesting of honey is as old as time. Basically, honey is a major ingredient in meals, drinks, baking and folk medications. Among other relevance, honey has been found to be very effective in soothing sore throat, checking the urge to cough, restoring natural skin conditions, cuts, burns, abrasions and to mention, but a few. These remedial roles have no doubt, enhanced human development and industrial performance in the world. Honey is also regarded as anti-bacterial due to the level of its acidic content. For instance, the manuka honey from New Zealand has been verified to kill over 250 variants of bacteria. Due to its antioxidant nature also, honey can be very effective in preventing cancers. Honey may however, not be safe for the ageing population due to its bacteria and yeast/fungi.

6.1 *The economics of honey production in africa and europe*

The honey industry in Africa has continued to generate income and foreign exchange for individuals, corporate organizations and the various governments in Africa. The honey industry has created jobs, especially in the rural areas and also serves as a means of diversifying the African economies. However, investment in the honey industry has been inconsistent, weak and painfully slow, worsening the level of unemployment and consequently aggravating poverty levels in the continent [137]. This means that a viable investment in the underutilized honey industries in Africa would be a major driver of economic growth and development in the continent. The study of [138] explicitly investigated the economic contributions of honey to the economy of Eastern Europe and the Americas, and found that honey production could be a major driver of economic growth in these regions.

As at 2021 the value of honey at the global honey market was about $ 9.21 billion and is expected to grow further to about 8.2 percent annually, due to increasing awareness on the need to maintain a healthy lifestyle [139]. Besides, Africans are beginning to know that honey is a major source of many nutritional ingredients such as vitamins, calcium, minerals and antioxidants, which are capable of improving metabolic activities and regulating blood pressure and blood sugar levels. Honey is also a relevant ingredient in the cosmetic and pharmaceutical industries. The uses and importance of honey for both domestic and industrial needs are numerous, hence the reason its world's demand is far higher than its supply [140]. Due to its limited supply, the product is expensive and this scarcity has also encouraged product adulteration, where sugar syrups are sold in place of original honey in the market. The research carried out by Grand View Research, an India and USA market firm revealed that a country's climatic condition is a major determinant of the production and supply of honey which is a reason why the South and North America, Europe and Asian countries are the major producers of the products, due to their more conducive climate for bees. The research further revealed that China has been a major exporter of honey to North America and Europe, while Europe holds the biggest market share of about 34 percent as at 2020. The report again revealed that honey is most consumed in the food and beverages industries, accounting for about 70 percent of the total market share in Europe. Honey was mostly used in baking products, soft drinks and alcoholic beverages as a flavor. The reports of the European Commission's Statistics for 2020 stated that about 60 percent of the honey consumed in Europe is produced in the continent of Europe, making the continent to be far more self-reliant in honey production and consumption when compared to other continents of the world. This is made possible by the huge investment in the European honey industry while the African scenario is quite the opposite as the production and supply chain of the honey industry has been neglected making the continent to be import dependent. Natural honey producers in Africa include Egypt, Central African Republic, Algeria, Mali, Cameroon, Rwanda, Morocco, Senegal, Madagascar and Zambia.

It must also be noted that honey production and supply are mostly influenced by market activities. In Nigeria for instance, the domestic markets are actively controlled by the rural communities. However, factors like insect pests, diseases, pesticide poisoning, poor skills development, knowledge sharing, bush burning, technical development, poor funding, lack of proper bookkeeping and to mention a few, are some setbacks to the production and supply of honey in Africa. A widening gap exists between actual production and expected production of honey in Africa. For instance, in 2018 the National Agricultural Programme (NAP) reported 2 million metric tons of liquid honey production as against 20 million metric tons expected to be produced. In the same year, to bridge the supply shortfall, Nigeria recorded a yearly import bill of 2 billion in 2017 with a world price of $ 4.5 billion.

Honey production and supply in Nigeria can be a major turnaround and means of diversifying the nation's weak economy. Speaking at the World Bee Conference, Ohio, Ambassador Lot Egopija explained the degree of underutilization of bee farming in Nigeria as a loss to the nation. He stated that the country is capable of realizing annual revenue of $ 10 billion from bee farming if fully utilized. He pointed to poor funding and gross neglect of the honey industry amongst others as major factors bedeviling the industry. According to him, a barrel of honey is currently more expensive than a barrel of crude oil in the world market. Other areas Nigeria can benefit from this is the supply of honey's by-products, like beeswax, bee venom and propolis which are essential inputs to the pharmaceutical, food and beverage industries. Furthermore, honey production can be a source of poverty alleviation, especially in the rural areas of the country through job creation for the rising number of the unemployed youths. This will also go a long way in curbing the evils that come with unemployment, like rising crime rate in the country. To achieve this feat, massive investment must be done in the honey industry that will improve the value chain and the government must also consider the regularization of local farmers. Furthermore, the products must to be standardized in order to enable them to compete favorably in the world market. Smokers, beehives, subsidies, and incentives should be provided to bee farmers to reduce their cost of doing business. A ready market should also be established in form of the defunct marketing board for the evacuation of honey and its by-products from bee farmers. This will encourage existing and attract new farmers into the honey production and supply business in the country.

Table 2. Microorganisms implicated in honey

S/N	Microorganisms implicated	Reference
1.	*Bacillus cereus*, *Bacillus badilus*, *B. laterosporus*, *Aerococcus sp.*, *Aspergillus niger*, *A. flavus*, *Penicillium sp.*, *Mucor sp.*, *Saccharomyces rouxii*, *Saccharomyces mellis.*	[94]
2.	*Bacillus amyloliquefaciens*, *B. simplex*, *B. licheniformis*, *B. pumilus*, *B. subtilis*, *B. cereus*, *B. thuringiensis*, *B. megaterium*, *Zygosaccharomyces mellis*, *Zygosaccharomyces rouxii*, *Aspergillus niger*, *Penicillium corylophilum*, *Debaromyces hansenii.*	[122]
3.	*Streptococci*, *Staphylococci*, *Micrococci*, *Bacilli*, *Lactobacilli*, *Escherichia coli*, *Klebsiella pneumonia*, *Micrococcus luteus.*	[101]
4.	*Klebsiella sp.*, *Staphylococcus aureus*, *Bacillus sp.*, *Aspergillus niger*, *Erothium sp.*, *Rhizopus stolinifer*, *Mucor sp.*	[139]
5.	*Bacillus cereus*, *B. megaterium*, *B. polymyxa*, *B. licheniformis*, *B. firmus*, *B. pumilus.*	[56]

6.2 *Analysis of top honey producers in africa and the rest of the world*

6.2.1 *China*

China has been the world's leading natural honey producer since the year 2014 with metric tons of about 447,007 in 2019 [141]. Natural honey production has contributed significantly to China's gross domestic product, generated foreign exchange for the country, created employment opportunities to millions of her citizens, diversified the economy, improved the standard of living of her people, enhanced industrial sector performance through the supply of relevant honey products and by-products, as inputs and to mention a few. Figure 1 below depicts the natural honey production statistics of China from 1961 to 2019, in metric tons.

The market for natural honey production in China has experienced some fluctuations over the years but reports released by Access Asia in 2021 revealed that production will continue to rise with rising demand for the product. Although, the country experienced a decline in production levels between 1998 and 1999 and some other periods due to bee diseases and unfavorable weather, it remained the world's leading producer of natural honey [142]. However, China's import of honey has been instigated by the demand from the Food Manufacturing industry, for a specific type of honey not produced in China. China's major natural honey buyers include Japan, Germany, Belgium, United States of America, Spain and the United Kingdom among others.

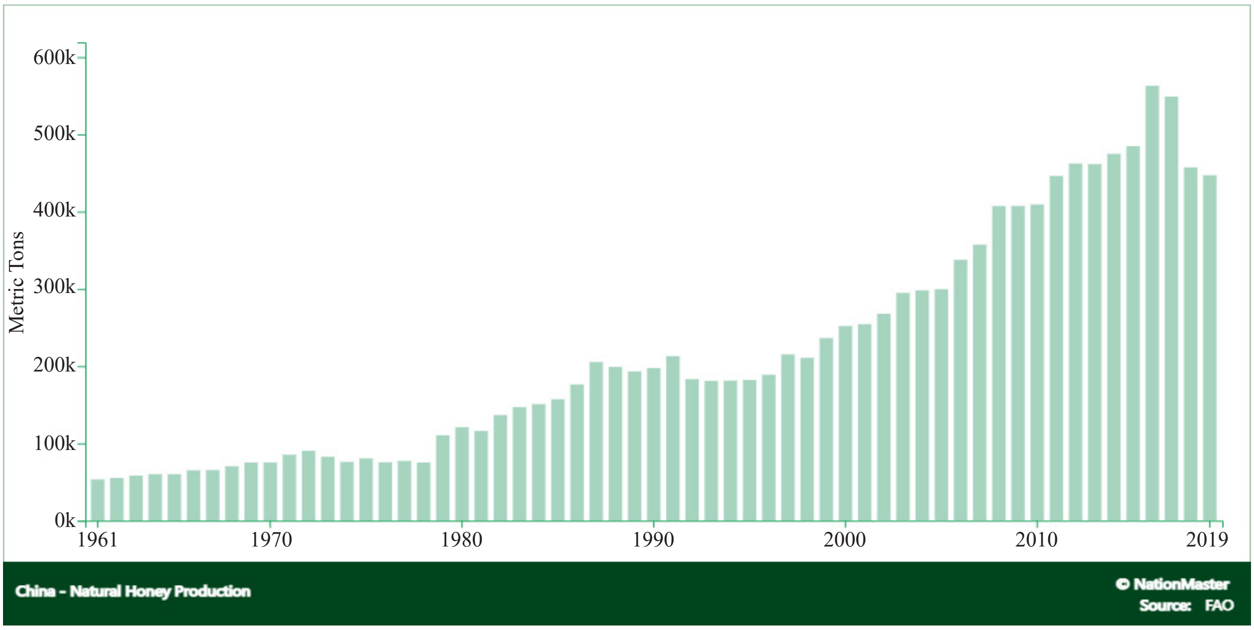

Figure 1. China's natural honey production in metric tons

6.2.2 *Turkey*

Natural honey production in Turkey was quite insignificant in the early 1980s as most of its local consumption was imported [143]. Currently speaking however, Turkey is ranked the second highest producer of natural honey in the world with an estimated 109,330 metric tons in 2019 [143]. Figure 2 below depicts the natural honey production statistics of Turkey from 1961 to 2019 in metric tons.

Natural honey has been one of Turkey's most important export products in recent years with about $ 31 million worth of honey in 2021 [144]. Been supported by good climatic conditions and relative humidity, the regions of Aegean, Muğla and Mediterranean coasts of Turkey produces most of the world's pine honey (nearly 90%) [145]. The country is therefore known globally for the largest pine honey production with about 25 bee sub-species. Natural honey in Turkey is produced in provinces like Mugla, Ordu, Adana, Aydin, Sivas and Mersin. A number of 10,000 beekeepers produce

40,000 tons of pine honey yearly in these regions. Aside pine honey, sunflower, thyme, chestnut and citrus honeys are also produced in Turkey [145].

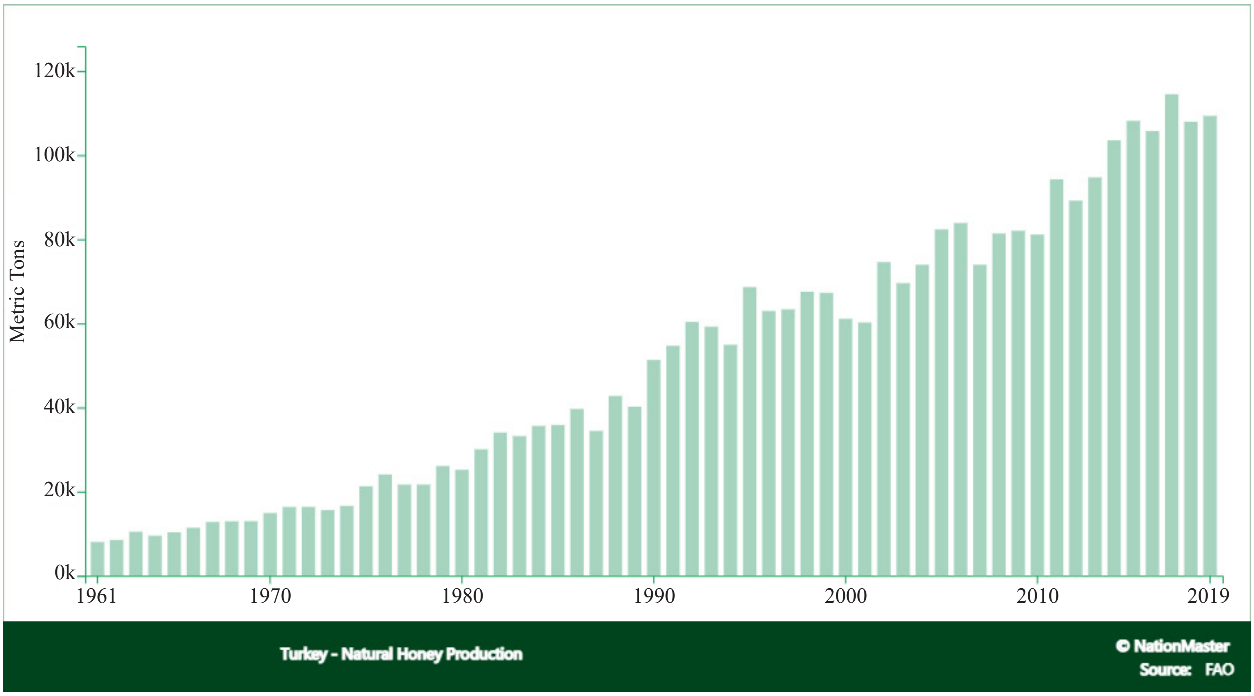

Figure 2. Turkey's natural honey production in metric tons

6.2.3 *Canada*

Natural honey production in Canada decreased by an average of 1.3 percent year on year, since 2014 but saw a rise to 80,345 metric tons in 2019 [143]. Canada is currently ranked as third in natural honey production worldwide. The country is also a major exporter of the product and its by-products to some countries in Africa and Europe. Figure 3 below depicts the natural honey production statistics of Canada from 1961 to 2019, in metric tons.

Majority of Canada's natural honey are locally consumed thus, leaving a small proportion for exports. For instance, the poor harvest experienced in 2020 due to the COVID-19 pandemic left just $ 47 million worth of exports, a 12 percent decline from 2019 [146]. Although, ranked 3rd in honey production worldwide, Canada's total honey imports from New Zealand and Brazil in 2020 alone, was $ 43 million [147]. These imports were organic honey of which Canada produces only in small quantity.

6.2.4 *Argentina*

Natural honey production in Argentina rose by an average of 0.8 percent year on year, but reached an average 78,927 Metric Tons in 2019 [148]. This output placed Argentina the fourth largest natural honey producer in the world as at 2019. Figure 4 below depicts the natural honey production statistics of Argentina from 1961 to 2019, in metric tons. Majority of Argentina's honey is produced in Santiago del Estero and it's known globally for its high quality [149]. According to Afrostat, honey production in Argentina reached its peak of 110,000 metric tons in 2005, with a lowest point of 17,000 metric tons in 1962. Argentina's major destinations for its honey are Belgium, Japan, United States of America and the United Kingdom among others.

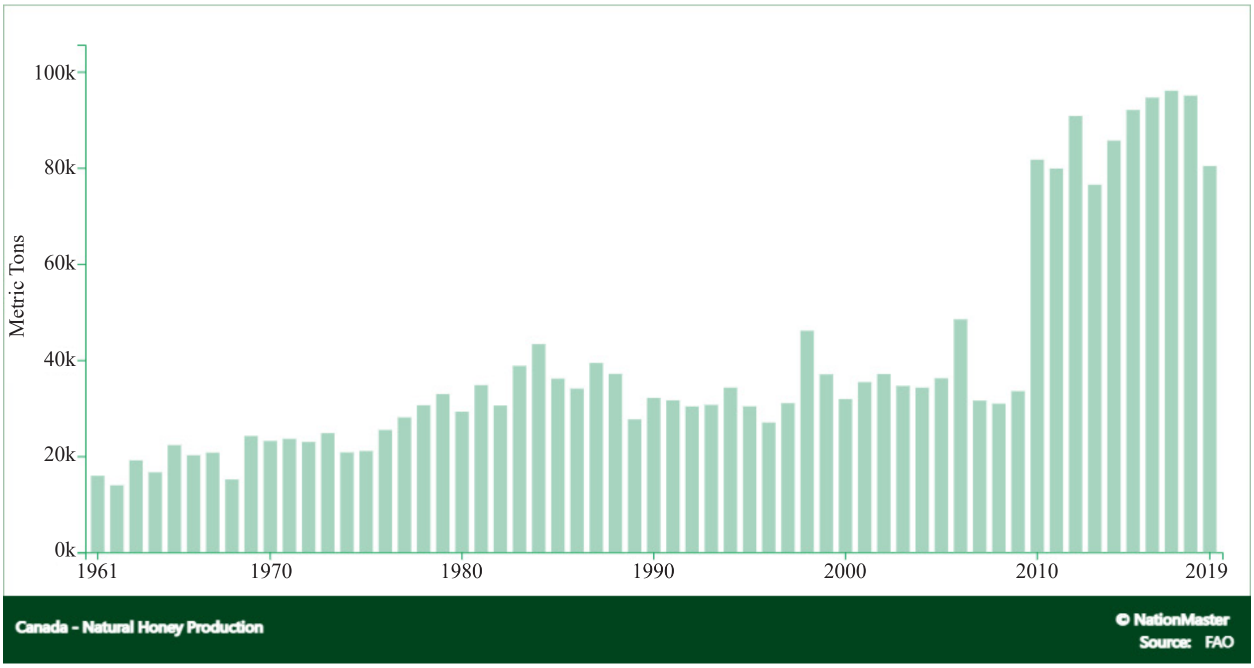

Figure 3. Canada's natural honey production in metric tons

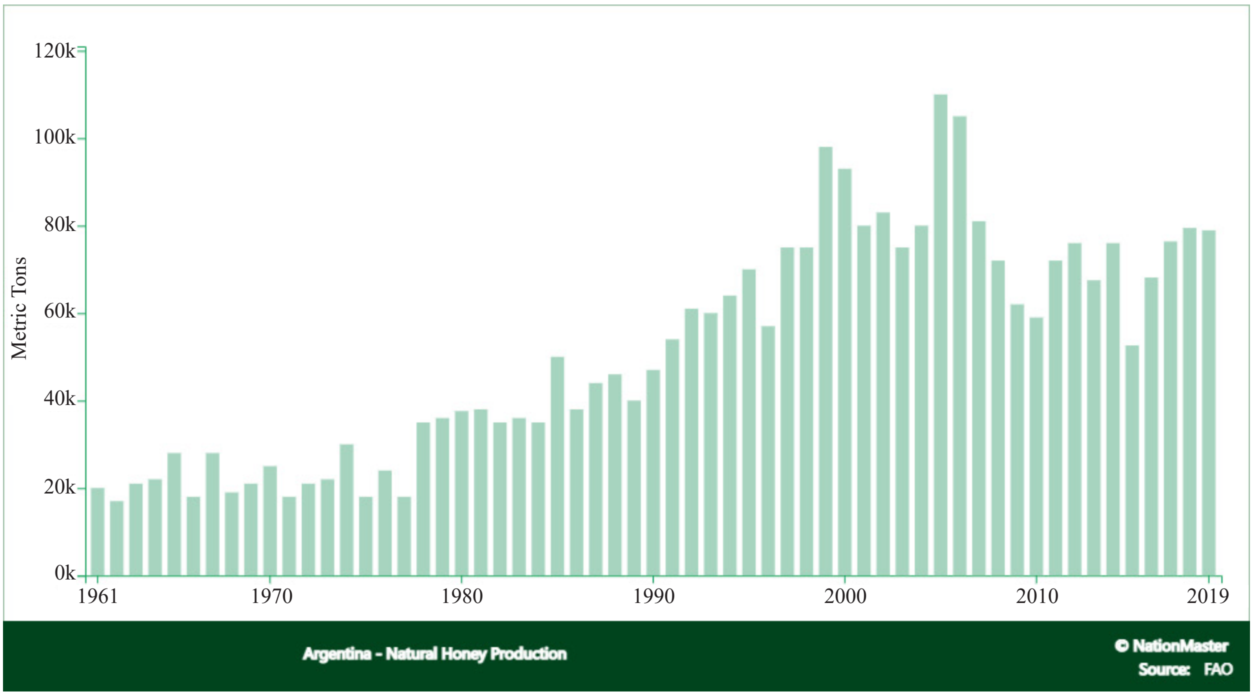

Figure 4. Argentina's natural honey production in metric tons

6.2.5 *Ethiopia*

Natural honey production in Ethiopia had risen continuously by 1.5 percent since 2014 year on year; with a production of 53,782 metric tons in 2019 [150]. Ethiopia was ranked 11th and 1st on world and Africa's natural honey production, respectively as at 2019 [151]. Figure 5 below depicts the natural honey production statistics of Ethiopia from 1961 to 2019, in metric tons.

As the leading producer of natural honey in Africa, Ethiopia has huge variation of biodiversity and agro-climatic weather conditions that encourage the existence of different species of honeybee flora and colonies [152]. Natural honey production in Ethiopia has been a major driver of employment and income generation, raw materials for industries, foreign exchange earnings, among others. However, lack of organized market channels, weak government support in the promotion of apiculture, unskilled manpower, and crude technology among others are major banes bedeviling the growth of natural honey production in Ethiopia.

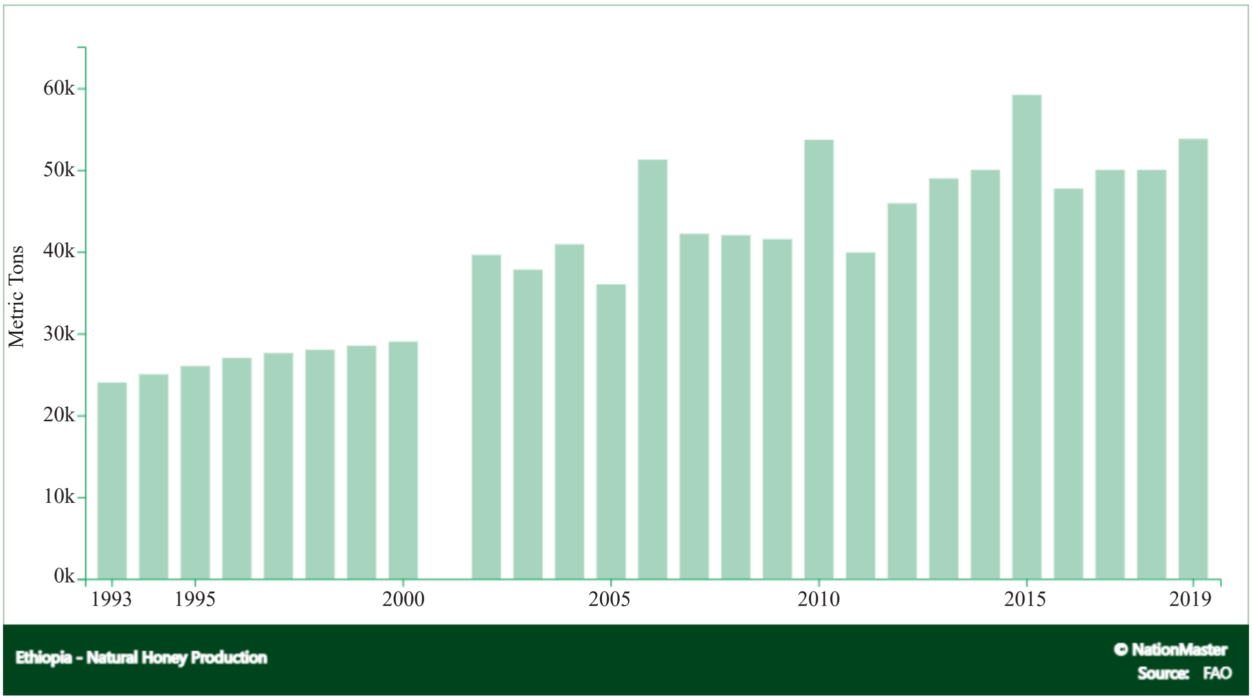

Figure 5. Ethiopia's natural honey production in metric tons

6.2.6 *Tanzania*

Natural honey production in Tanzania rose by 0.5 percent year on year, since 2014; with an average production of 30,937 Metric Tons in 2019 [153]. Tanzania is ranked 14th and 2nd in the world and Africa, respectively in natural honey production as at 2019. Figure 6 below depicts the natural honey production statistics of Ethiopia from 1961 to 2019 in metric tons.

Natural honey production is well known in provinces like Katavi, Tabora, Kigoma, Singida, Mbeye, Songwe, Ruvuma and Morogoro, in Tanzania [154]. However, the lack of markets, climate change, bush burning and invasion from honey badgers are some of the banes bedeviling the honey industry in Tanzania. The honey industry in Tanzania had been a major factor to the country's economic growth and development for many years. For instance, the honey industry generates an annual income of about $ 1.7 million and employs about 2.1 million people from the rural areas [155]. The United Kingdom, United States of America, Japan, Germany and the Netherlands are the major buyers of Tanzania's natural honey.

6.2.7 *Angola*

Natural honey production in Angola recorded an insignificant 0.1% year on year decline since 2014 with a production of 23,428 metric tons in 2019. Angola is ranked the 3rd highest natural honey producer in Africa and 17th in the world (Figure 7).

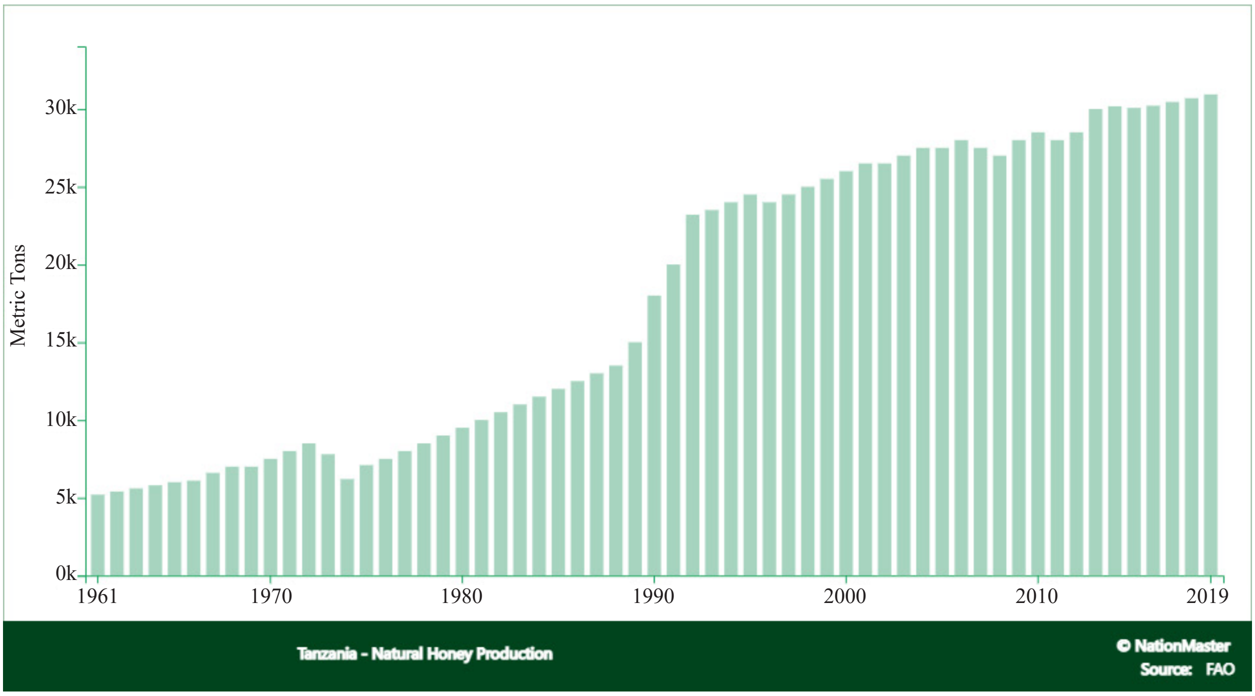

Figure 6. Tanzania's natural honey production in metric tons

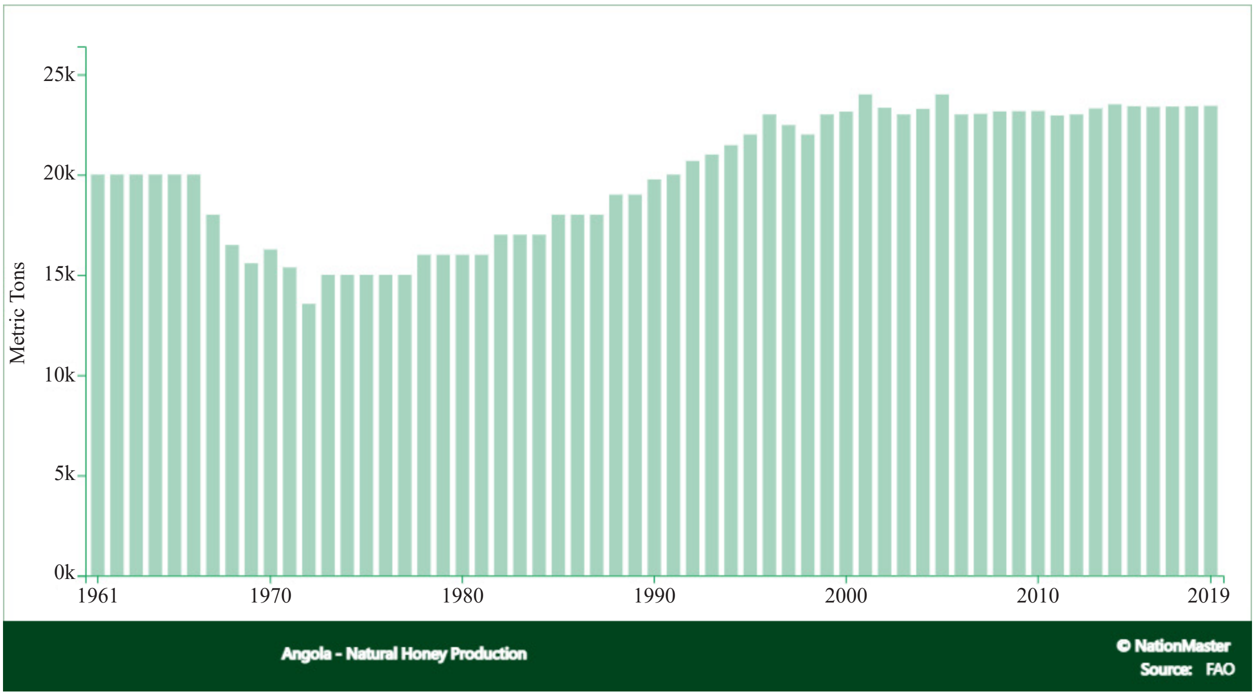

Figure 7. Angola's natural honey production in metric tons

Angola diversified her economy when oil prices crashed in 2014 and since then the Angolan government had focused on other sectors like the honey industry. In 2020, Angola was able to produce 90 tons of natural honey and with the application of modern technology production is expected to increase to 200 tons per year in the recent future [156]. Angola enjoys favorable weather that encourages the production of natural honey all year round. Crude honey production technologies, poor government support amongst other factors, are banes to the growth of the Angolan honey industry.

7. Conclusion

Natural honey is high in nutrients and has antioxidant, anti-inflammatory, and antibacterial effects. Honey has also been proven to inhibit and disrupt biofilm development, aid in wound healing, and act as an immunomodulatory and gastroprotective agent. Further research into its composition and the identification of active components are required before honey may be used as an alternative treatment in modern medicine. Natural honey is recommended as a good dietary supplement, and the use of honey in the treatment of many metabolic and pathogenic diseases warrants further research.

Availability of data and material

All data will be made available upon reasonable request.

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Authors' contributions

GE, FO, PA, EA, JA, EA, RL were responsible for the conception and design of the study; GE performed data collection. GE performed data analysis and drafted the article. GE supervised the study and contributed to data analysis, interpretation, and critical revisions. All authors approved the final manuscript.

Conflict of interest

The authors have no competing interests.

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