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Physico-Chemical and Physiological Values of Honey and Its Importance as a Functional Food

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Abstract

Honey is classified based on processing, and has physical, chemical and nutritional properties. It has wide acceptability as a complementary and alternative medicine, with extensive use for all human ailments including cancer. The medicinal potency of honey evolved from its biochemical activities and effects as a functional food. Honey contains all the six classes of dietary requirement of food, and can go for a complete meal. The availability of honey in natural state, its influence on physiological processes in all organs and provision of additional health benefits beyond nourishment gives it more recognition as a functional food. The inclusion of honey in infant and children diets, and use as food sweetener is nutritionally rewarding. The presence of several nutraceuticals, phytochemicals and other bioactive substances exerts influence on blood chemistry and body metabolism of honey consumers. This enhances biochemical activities, with consequent physiological modifications in the body. The bioactive substances in honey interact uniquely and work in synergy to give synergistic multiple ingredients factor. This factor helps honey to influence vital processes of the body, covering virtually all organs within the organism. The beneficial effects of honey as a medicinal agent are attributed to its significance as a functional food.

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Abbreviations: CAM: Complementary and Alternative Medicine; GI: Glycaemic Index; GIT: Gastrointestinal Tract: NH: Natural Honey; UMF: Unidentified Mystery Factor; SMIF: Synergistic Multiple Ingredients Factor

Introduction

Food is eaten by man and animals to supply nutrients for growth and development. Natural honey (NH) is a sweet, flavourful, viscous, liquid food produced by honey bees as blossom honey by secreting nectars of flowers, and forest honey by secreting the exudates of plant sucking insects (Aphids) (Figure 1)[1,2]. NH contains more than 300 substances, but its main composition is sugars, primarily fructose and glucose and little amount of fructo-oligosaccharides[2-5]. The nutritional and chemical constituents of honey are greatly influenced by the plants on which the bees feed. However, it is noteworthy that irrespective of the floral source of honey, all types of honey exhibit different biochemical activities and potency as a medicinal agent more than conventional drugs[3].

The wide acceptability and use of natural honey as a complementary and alternative medicine (CAM) for most ailments evolved from its effects as a functional food. Functional foods do not only provide nourishment and energy for growth and sustenance, but also enhance vital processes within the body[6]. The medicinal attributes of honey appears to overshadow its importance as a functional food. Consequently, several literatures are rife with ancient uses of honey as CAM, with relevance to modern day health

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care[2,3,7–16], supported by evidence-based clinical data[16-25], with little attention given to honey's nutritional functions[2,4,16,26–28]. Thus, the records of honey as a functional food are incipient. However, it has been observed since antiquity that NH is not only important for its medicinal attributes[2,3,7,9,12,16,27,29], but also useful as food sweetener[1,26,30,31]. Hence, the need to review relevant materials on the use of honey as a functional food becomes imperative. The survey also involves the effects of honey's bioactive compounds on body systems.

Figure 1: Bees in the process of producing honey in different geographical locations.

Honey Classification

Honey is classified severally and labeled differently after packaging, and the classes include raw, granulated, pasteurized, strained, ultrafiltered, ultrasonicated, chunk, comb, dried and whipped[1,31,32]. Raw honey is that which exists in the beehive or as obtained by extraction, settling or straining, with minimal processing devoid of heat treatment. Figure 2 shows the pictorial representation of modern bee hives[1].

Figure 2: Modern bee hives containing raw honey.

Granulated honey

Granulated honey is obtained when the honey's glucose content has spontaneously crystallized from solution as the monohydrate[2]. The granulated or crystallized honey can be returned to a liquid state if stirred in a container placed in warm water at 120ºF (49ºC). Pasteurized honey is that produced when the honey is heated to 161ºF (71.7ºC) in a pasteurization process, and this destroys yeast cells and also liquefies microcrystals in the honey, which delays the onset of visible crystallization.

Strained honey

Strained honey has been passed through a mesh material to remove particulate material such as wax, propolis, and dirts without removing pollen, minerals or enzymes. Ultrafiltered honey is processed by very fine filtration under high pressure by heating honey to 150–170ºF (65–77ºC), such that it can easily pass through the fine filter to remove all extraneous solids and pollen grains, as shown in Figure 3[2].

Figure 3: Filtration of raw honey.

Ultrasonicated honey

Ultrasonicated honey is obtained by a non-thermal process, in which yeast cells are destroyed and crystals formation is inhibited. Chunk honey is packed in wide mouth containers consisting of one or more pieces of comb honey immersed in extracted liquid honey. Comb honey is that still in the honeybees' wax comb, and it is traditionally collected from honey supers by using standard wooden frames in which the comb is cut out in chunks before packaging. Typical wooden frames are shown in Figure 4[1]. Dried honey has the moisture extracted from liquid honey to create completely solid, non-sticky granules, and this process may include the use of drying and anticaking agents. Whipped or creamed honey contains a large number of small crystals and the process produces honey with a smooth, spreadable consistency.

Figure 4: Typical wooden frames used in producing comb honey.

Physical properties

The physical appearance of honey varies with the methods of extraction, processing, packaging and preservation[1,34,35]. However, there are basic properties associated with this natural product, irrespective of the procedures involved in the preparation[30,32,36]. These include water content, particulate composition and water absorption. Honey contains about 16% water and about 80% suspended particles[30,35]. Freshly extracted honey is a viscous liquid food, and its viscosity depends on the various honey constituents[1,2]. Hence, the viscosity is greatly influenced by the composition of honey, mainly its water content. The ability of honey to absorb and hold water from the environment is described as hygroscopicity. Honey will absorb moisture from air at a relative humidity of about 60%[30]. Another factor affecting the physical appearance of honey is surface tension, which is influenced by the colloidal substances in the honey, a reflection of the honey's botanical origin[34]. The surface tension and high viscosity of honey cause the foaming appearance of honey[37].

The other physical features and characteristics of honey include taste, smell, colour, heat and crystallization[2,30]. Honey has a sweet smell and taste, and is regarded as a sweetener, be-

cause it contains a very sweet sugar, fructose naturally mixed proportionately with another sugar, glucose[4,35]. The colour of liquid honey varies from clear and colourless, yellow, amber to dark amber or black. The colour varies with honey's origin, age, and storage conditions, but transparency or clarity depends on the amount of suspended particles such as pollen[2,34,37]. Other honey colours are bright yellow (sunflower), reddish undertones (chest nut), greyish (eucalyptus) and greenish (honeydew). Heat also affects the physical appearance of honey, including colour, crystallization, taste, and fragrance. In fact, natural honey becomes dark in colour when heated. Honey crystallization results from the formation of monohydrate glucose crystals, which vary in number, shape, dimension, and quality with the honey composition, preservation and packaging procedures[32,34]. However, irrespective of the storage conditions, honey may crystallize over time. Figure 5 shows the process of honey crystallization Figure 5.

Figure 5: Honey crystallization.

Crystallization does not affect the flavour, quality or nutritional content of honey, though it affects texture and colour. Honey turns lighter in colour as a result of crystallization, because the glucose crystals formed are white. In addition to glucose crystals present in crystallized or granulated honey, water quantity also affects rate of crystallization[2]. The lower the water and the higher the glucose content of honey, the faster the crystallization[37]. The rate of crystallization is also influenced by storage temperature, and the specific mixture of sugars and trace compounds in the honey. Tupelo and acacia honeys are exceptionally slow to crystallize, while goldenrod will often crystallize while still in the comb. As aforementioned, heat treatment affects the physical properties of honey, including crystallization. Thus, honey can be crystallized at a low temperature of between 50 and 70ºF (10 and 21ºC), while the dissolution of the crystals to obtain a more fluidly liquid honey can be achieved by indirect heating of the honey to a higher temperature of about 120ºF (49ºC).

Chemical composition

Natural honey contains more than 300 bioactive substances, but it is mainly composed of water and sugars, primarily fructose and glucose, which accounts for 95–99% of honey dry matter, and about 4–5% of fructo-oligosaccharides[2–5,26,30,38,39]. Other sugars include disaccharides such as maltose, sucrose, isomaltose, turanose, nigerose, meli-biose, panose, maltotriose, melezitose and oligosaccharides[2,5,38,39]. The nutritional and chemical constituents of honey are greatly influenced by the plants on which the bees feed. The other chemical substances found in honey are amino acids, antibiotic-rich inhibine, phenol antioxidants, vitamins, minerals, enzymes, nitrogenous compounds, and trace elements[3,30]. In addition to the phenol compounds, flavonoids are antioxidants also found in honey (Figure 6)[40]. These contribute immensely to the value of honey as a functional food. Potassium is the major chemical element, followed by calcium, magnesium, sodium, sulphur and phosphorus. These and the other chemical elements present in honey are listed in Table 1. The trace elements include iron, copper, zinc and manganese[1,29,40,41] Table 1.

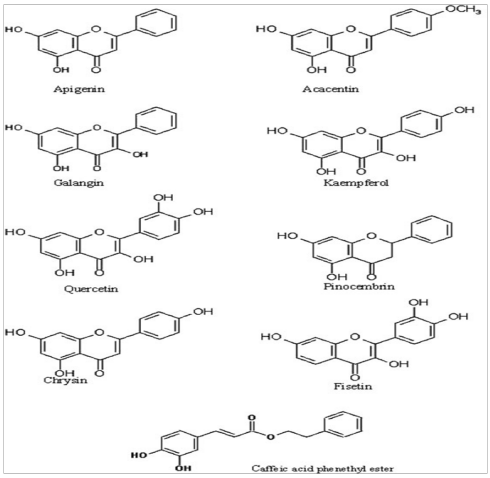

Figure 6: Chemical structures of flavonoids found in honey.

Table 1: Chemical elements found in honey (mg/100g).

Element	Amount	Element	Amount
Aluminium (Al)	0.01 – 2.4	Magnesium (Mg)	0.7 – 13
Arsenic (Ar)	0.014 – 0.026	Manganese (Mn)	0.02 – 2
Barium (Ba)	0.01 – 0.08	Molybdenum (Mo)	0 – 0.004
Boron (B)	0.05 – 0.3	Nickel (Ni)	0 – 0.051
Bromine (Br)	0.4 – 1.3	Phosphorus (P)	2 – 15
Cadmium (Cd)	0 – 0.001	Potassium (K)	40 – 3500
Calcium (Ca)	3 – 31	Rubidium (Rb)	0.040 – 3.5
Chlorine (Cl)	0.4 – 56	Selenium (Se)	0.002 – 0.01
Chromium (Cr)	0.01 – 0.3	Sodium (Na)	1.6 – 17
Cobalt (Co)	0.1 – 0.35	Silicon (Si)	0.05 – 24
Copper (Cu)	0.02 – 0.6	Strontium (Sr)	0.04 – 0.35
Fluoride (F)	0.4 – 1.34	Sulphur (S)	0.7 – 26
Iodide (I)	10 – 100	Vanadium (V)	0 – 0.013
Iron (Fe)	0.03 – 4	Zinc (Zn)	0.5 – 2
Lead (Pb)	0.001 – 0.03	Zirconium (Zr)	0.05 – 0.08
Lithium (Li)	0.225 – 1.56		

There are organic acids in honey, constituting 0.57% of honey and include gluconic acid which is a by-product of enzymatic digestion of glucose. The organic acids are responsible for the acidity of honey and contribute largely to its characteristic taste[37]. The enzymes present in honey are glucose oxidase, invertase (saccharase), diastase (amylase), and catalase. These enzymes play an important role in the formation of honey, and its bioactivity as a functional food[1,37,41,42]. The enzyme, glucose

oxidase produces hydrogen peroxide (which provides antimicrobial properties) along with gluconic acid from glucose which helps in calcium absorption. Invertase converts sucrose to fructose and glucose. Dextrin and maltose are produced from long chains starch by the activity of the enzyme, amylase. Catalase helps in producing oxygen and water from hydrogen peroxide[43].

Nutritional profile

Natural honey is a healthy, easily digestible, wholesome and energy rich food. It has all the main components of a diet thus: carbohydrates, proteins, lipids, water, vitamins and minerals. In fact, it is best described as a complete meal in nutritional parlance. The principal carbohydrate constituents of honey are fructose (32.6–43.4%) and glucose (28.5–37.6%), which represents 85 to 95% of total sugars that are readily absorbed in the gastrointestinal tract[4,35,39,44]. Other sugars include disaccharides such as sucrose and maltose also complement the carbohydrate block of the diet[4,35]. Water is the second most important nutritional component of honey. Honey contains proteins only in minute, 0.1–0.5 % quantities[44-46]. According to a recent report, specific protein quantities differ according to the honeybee origin[47]. The vitamins that partake in the digestive function of honey eaters include vitamins C, B_1 (thiamine) and B_2 complex vitamins like riboflavin, nicotinic acid, B6 and panthothenic acid as all these are found in honey[35-37]. The other micronutrients found in honey are minerals which include calcium, copper, iron, magnesium, manganese, phosphorus, potassium and zinc. The detailed list of vitamins, minerals, other micronutrients and trace elements found in honey as discussed elsewhere[27,36], is shown in Tables 1 and 2. The high nutritional profile of honey with wide range of nutrients (although mostly in minute quantities), encourages its use as food. Due to the low quantities of some of these nutrients, it is advisable to take honey in large quantities (70–90 g daily) to meet the body's requirement, and get beneficial effects as a functional food[20,21,27,35,48–50].

Table 2: Nutritional composition of honey as reported from previous studies (Mean±SEM).

Proximate analyses	Amount	Proximate analyses	Amount
Water (%)	15.92±0.07	Protein (%)	0.42±0.06
Carbohydrate (g/100g)	88.97±1.71	Fat (%)	0.53±0.01
Fructose (g/100g)	43.35±0.02	Thiamine (mg/100g)	0.01±0.00
Glucose (g/100g)	37.64±0.01	Riboflavin (mg/100g)	0.02±0.00
Sucrose (g/100g)	2.03±0.05	Niacin (mg/100g)	0.15±0.01
Maltose (g/100g)	2.75±0.02	Vitamin B5 (mg/100g)	0.07±0.03
Oligosaccharides (g/100g)	3.11±0.08	Pyridoxine (mg/100g)	0.17±0.02
Erlose (g/100g)	0.81±0.06	Folic acid (mg/100g)	0.006±0.00
Melezitose (g/100g)	0.09±0.03	Ascorbic acid (mg/100g)	2.35±0.25
Glycaemic sugars (%)	76.71±1.55	Vitamin K (mg/100g)	0.025±0.00
Energy (MJ/Kg)	15.56±0.21	Other nutrients (%)	0.53±0.00

Functional food

A functional food is similar in appearance to, or may be, a conventional food eaten as part of a usual diet to provide varying amounts of nutrients, or for enrichment as a dietary supplement for beneficial effects[6]. All foods are considered functional as they deliver nutritional components like proteins for muscle repair, carbohydrates for energy, or vitamins and minerals for cell function. Honey is a liquid food containing all the six classes of nutrients expected in a given diet thus: carbohydrates, proteins, fats, water, vitamins and minerals[30,35,36]. These dietary requirements are found in honey in appropriate amounts (Tables 1 and 2). Honey is eaten raw after little or minimal processing as liquid, crystals or other types. Natural honey constitutes an important ingredient in food recipes for domestic and industrial consumption[1,4]. The uses of honey as food include flavourant and sweetener in dairy products and fruit juices, as well as industrial production of several non-alcoholic beverages[2]. These drinks nourish the body and boost energy.

In addition to the provision of nutrients and energy to sustain growth, a functional food must have additional health benefits beyond nourishment[40]. The Academy of Nutrition and Dietetics defines a functional food as: a food that provides additional health benefits that may reduce disease risk and or promote good health[51]. Other authors opine that functional foods are natural food substances that do not only have potentially positive and beneficial effects on health beyond basic nutrition, but also support other vital processes of the body[6,52,53]. Honey contains dietary components of a meal for basic nutritional functions[1,27,35], and bioactive compounds that interact uniquely and work in synergy to give 'synergistic multiple ingredients factor' (SMIF). The factor, SMIF significantly contributes to the beneficial health effects of honey[35,36], facilitating its use as a complementary and alternative medicine (CAM) to most diseases. This forms the basis surrounding the different health claims attributed to natural honey, and its significance as a functional food in promoting growth and other physiological processes.

Health claims

The use of honey as a complementary and alternative medicine is dated back to the existence or discovery of this natural product[2], accompanied by several health claims of its veracity for almost all known pathological conditions of man[2,16,27]. The therapeutic use of honey cut across all ages, organs and systems, and even devoid of gender barrier[12,13,54,55]. This ranges from acute diseases to chronic infections, and include neonatal conditions of diarrhoea and measles; external body conditions such as wounds; gastrointestinal ailments like diarrhoea, ulcer and gastritis; ophthalmological diseases of blepharitis and conjunctivitis; dental infection of caries; metabolic disorders such as diabetes and metabolic syndrome; to the deadly neoplastic diseases of cancer, example of which is vulvectomy[1,23,27,35–37,43,56–60]. The other conditions being treated with honey include cough, stomach ache, body pain, menstrual pain, allergic reactions, urinary tract infections, bacterial infections, respiratory distress, viral infections, mycoses, hay fever and leprosy[1,57,58]. To add to the growing list of health claims of honey, its use in radiology and nuclear medicine has also been recently identified[61-63].

The therapeutic and surgical management of wounds using this natural healing agent appears to be the most widely investigated amongst the various health claims of honey's ve-

racity[2,16–18,27,56–58,60,64–66]. The mechanisms surrounding honey's efficacy as a wound healing agent abounds as the number of manuscripts, but all show that NH is functional as it heals where conventional therapy fails[27,57,58,60]. Another notable health claim of honey as CAM receiving prominence for scientific backing is the antimicrobial effect[3,29,37,39,43,44,56]. According to the renowned researcher of honey, the efficacy of honey as a therapeutic agent can be traced to the UMF, unidentified mystery factor found only in the jelly bush honey of New Zealand[67]. The potency of all honey types from different geographical locations and botanical origins as natural healing substance calls to question the presence of healing factor only in the New Zealand honey[34,68]. In addition, the synergism of action associated with the honey's carbohydrate components, nutraceuticals, and other phytochemicals show that the healing factor(s) of honey appears to be identifiable and not in mystery[4,5,27,30,41,42,46,47,69]. These later authors give credence to the conclusion drawn from an extensive study on the metabolic health effects of honey from our laboratory that the mechanistic insights into the healing and protective factor(s) of honey should be focused on SMIF, 'synergistic multiple ingredients factor'[36]. By and large, 'UMF' and or 'SMIF', the fact remains that NH contains bioactive compounds producing functional effects with biological significance in all organs and systems of the body.

Growth and energy boost

Food is eaten for body nourishment, metabolic activities, growth and healthy living. The provision of dietary enrichment with a functional food such as NH gives additional health benefits, in addition to the enhancement of body functions. Honey promotes physiological processes such as growth and enhances physical activities like exercise and other sporting events. Regular consumption of natural honey provides all these beneficial effects. In fact, honey is a complete meal, as previously discussed[35,36]. It contains major components of a balanced diet, including micronutrients that will enhance the digestion and absorption of these major dietary components to promote healthy growth[27,35]. The constituents also include bioactive compounds required for metabolism and physiological processes. In two separate nutritional studies at different laboratories in Nigeria and South Africa, Ajibola and co-workers recorded enhanced body weight gain by the rats fed floral honey[35,69]. In 2008, Chepulis and Starkey fed New Zealand forest honey to 8-week old rats for 52 weeks to assess weight gain[70]. These workers show that growth influence of honey in rodents is due to increased bone growth and mineralisation[35,70], probably due to the calcium content of honey. Our recently published data from another study on rats fed with honey-enriched diets confirm the linear growth influence of honey[54]. In one comparative study, Ajibola and co-workers confirm the growth stimulating property of honey, as they report enhanced development of the intestinal morphology at both gross and microscopic levels[55]. The authors conclude from these findings that the biological significance of the improved cell growth by honey is enhanced gastrointestinal function.

Honey as a natural mixture of fructose-glucose along with oligosaccharides, proteins and micronutrients appears to be an energy booster when eaten by athletes engaged in sporting activities and healthy individuals at sedentary[1,2,4,5,26–30,47]. The glucose in honey is absorbed by the body quickly and gives an immediate energy boost, while the fructose component is absorbed more slowly providing sustained energy. The data obtained from the Sports Nutrition and Exercise Laboratories support these hypotheses[43,71]. These American researchers demonstrate that honey is an effective and functional carbohydrate source for athletes before and after resistance training and during endurance exercise. In another similar trial, low (honey) or high GI (glucose) carbohydrate gels were administered on cyclists travelling a distance of about 65 km to test the effects on the athletes' performance[72]. The results of the cycling event show that performance obtained by eating honey surpassed that observed in the athletes fed with glucose.

The consumption of energy booster before, during and after physical exercise improves individual's performance and increases muscles rejuvenation. The dietary enrichment with honey provides more than energy boost of muscle recuperation and glycogen restoration, as studies by Kreider and other workers show that NH sustains a favourable blood sugar concentration and increase in heart functions of consumers after training[71,73]. The experimental trials show that honey is a well-tolerated liquid food. These findings suggest that honey as a functional food is a better substitute than commercially available sporting activities enhancers such as glucose and maltodextrin/protein mixture.

Food preservation and sweetening

Previous studies show that NH contains several bioactive compounds, which include antioxidants[1,19,27,30,40–42,57,74]. In their analysis of the phytochemical composition of some honey types, some workers agree with this submission and conclude that honey contains important phenols, flavonones and carotenes with high antioxidant capacity[3,75]. Hydrogen peroxide and non-peroxide components of honey such as antioxidants inhibit the growth of certain bacteria (*Shigella species, Listeria monocytogenes*, and *Staphylococcus aureus*), thus helpful and useful in food preservation[37]. The presence of small amounts of *Clostridium botulinum* in honey can also promote this natural product (NH) as a food preservative. This bacterium has a good potential to be used as a natural source of antioxidants to reduce negative effects of polyphenol oxidase browning in fruit and vegetable processing[43,76]. The bioactive components of NH include flavonoides (chrysin, apigenin, kaempferol, pinocembrin, quercetin, galangin and hesperetin), phenolic acids (caffeic, ellagic, ferulic and p-coumaric acids), tocopherols, catalase, superoxide dismutase, glutathione, ascorbic acid, Maillard reaction products and peptides[40,75-79]. In the opinion of the authors, most of these compounds work together to provide a synergistic antioxidant effect[77-79], as a part of SMIF[36]. These findings make a suggestion by Johnston and co-workers pertinent[77]. These workers opine that honey, as a natural antioxidant, may serve as an alternative to some preservatives such as sodium tripolyphosphate in food preservation to delay lipid oxidation[77].

The main sugar constituents of honey, sweet smelling fructose and glucose promote it (NH) as a sweetener in different dishes and desserts. Honey is a suitable sweetener in fermented milk and other dairy products, as it promotes the growth of common bacteria like *Streptococus thermophilus, Lactobacillus acidophilus, Lactobacillus delbruekii* and *Bifidobacterium bifidum*[31] which are important for maintaining the health of the gastrointestinal tract[43,80]. This prebiotic effect is attributed to the presence of a variety of oligosaccharides in honey[39,43,80]. A

prebiotic is a non-digestible dietary supplement that modifies the balance of the intestinal microflora stimulating the growth and activity of the beneficial organisms and suppressing potentially harmful bacteria[38,81]. The main prebiotic found in NH is fructo-oligosaccharides[5,80,82,83].

The presence of antioxidants in honey is also a plus for its (NH) use as a food sweetener. In one Californian nutritional study, the workers submit that the protection of human beings from the damaging effects of free radicals and reactive oxygen species is through the absorption of antioxidants from foods such as honey[74]. The report of their study in which two buckwheat honey treatments were administered to 37 healthy human adults at the rate of 1.5 g/kg body weight, with corn syrup as control, show increased ($p < 0.05$) plasma total-phenolic content and plasma antioxidant in honey eaters[74]. This supports the concept that phenolic antioxidants from processed honey are bioactive compounds with protective effects against oxidative damage[40,75]. These workers advocate for the substitution of honey as traditional sweetener in some foods for enhanced antioxidant defence system in healthy human adults.

Gastrointestinal functions

The use of honey as a sweetening agent in foods has additional nutritional advantages over refined sugars, providing some amount of micronutrients and phytochemicals[30]. These bioactive substances include several enzymes which enhance gastrointestinal functions, such as digestion and absorption. The biological significance of these vital processes is trophic effects of organs and consequently organisms as demonstrated in our recent studies on animal models[54,55]. The predominant influence of natural honey on organs' macroscopic growth was shown by the caecum and pancreas in the experimental male rats[55]. The increased relative weight of these organs in the honey-fed rats could enhance enzymatic production by the pancreas and digestive functions by intestinal microflora of the caecum. The increase in caecal weight was attributed to the trophic effect on the caecum by osmotically active constituents of honey that are probably not absorbed from the small intestine[30,35]. At the microscopic level, there was also enhanced intestinal villi growth of the honey eaters with improved digestive functions and better feed utilisation[55]. These contributed immensely to the healthy growth of the rodents as seen in another related study[54].

Another nutraceutical potential of honey is provision of calcium. Honey consumption provides calcium, which is readily absorbable and strengthen bone mass development. This can help reduce the risk of osteoporosis or low bone mass, the causative agent of fractures, especially in old individuals. The research in animal models show that calcium absorption increased correspondingly with increased honey intake[84]. The additional benefit of eating honey as a source of energy over the commonly used artificial sugar is that, the sugar constituents of NH are present as simple sugars[30]. Unlike the refined sugar (sucrose) which normally has to undergo the processes of digestion into simpler forms prior to their absorption, the sugar molecules in NH are in pre-digested forms, and can be directly absorbed into the human system.

In addition, the gastrointestinal tract (GIT) contains lot of essential and beneficial bacteria, especially bifidobacteria for the maintenance of life and good health. It has been suggested that one can increase the bifidobacteria populations in the GIT by consuming foods with rich supply of prebiotics such as natural honey[80,85]. As earlier defined, prebiotics are substances that facilitate the enhanced growth and the biological activity of these good and beneficial bacteria[34,81]. Several experimental trials involving both in-vitro and in-vivo studies have been documented on the importance of dietary supplementation with natural honey on the growth of these beneficial bacteria (bifidobacteria and lactobacilli) and their prebiotic effects in the GIT[5,31,80,85–87]. The previous findings of Ajibola and co-workers also confirm this beneficial effect of dietary enrichment with honey in their recent nutritional studies[27,35,36,54,55].

The consumption of honey is important in human digestion, and this effect is produced by the honey's constituents of oligosaccharides[5,80,85]. One comparative study on natural (honey) and artificial (sucrose) sugars show that honey increased both in-vitro the beneficial bacteria, lactobacilli, as well as in-vivo (within the small and the large intestines of experimental rats), while sucrose had no effect[88]. In some cases, the consumption of relatively large amounts of NH (between 70 to about 95 grams) can produce a mild laxative effect in people with fructose malabsorption or inadequate absorption[89,90]. Generally, honey has a laxative effect on the digestive system of individuals.

Food for children

NH is a good and healthy source of nourishment for infants and children. Some customs and traditions even advocate and encourage the feeding of honey to newly born babies[7,8,13,28,91]. The feeding of honey to neonates and children could be beneficial instead of sweets and other sugary substances that they often hanker after[27,35,36]. This presumption is supported by the recent findings of other workers from an exclusive study on the effects of honey on paediatric patients involving about 80 trials[92]. These authors conclude that the use of medical honey is safe and encouraging in the field of paediatrics. Apart from providing basic nutritional requirements, NH also confer health benefits when consumed by children, as reports have it that honey has been used to ameliorate the pathological effects of neonatal diarrhoea and gastroenteritis[13,93].

Dietary enrichment during the peri-natal suckling period could enhance gastro-intestinal development in neonates, with long lasting and apparently irreversible beneficial effects on vital body processes[94]. It is now an established fact that feeding honey to infants will improve memory and growth, reduce anxiety and enhance the children's performance in later life. In 2009, Chepulis and co-workers give scientific credence to this beneficial practice in their behavioural study in animal models[95]. They fed 8 weeks old rodents with diet enriched with either honeydew honey or sucrose, and control group with sugar-free diet to simulate New Zealand human diets. These workers document improved spatial memory and reduced anxiety in the honey-fed rodents unlike the other groups over the twelve months trial period[95]. The workers conclude that early introduction of honey diet is beneficial and can improve memory and abate cognitive decline associated with aging.

The application of honey in human infant nutrition also revealed some interesting and beneficial observations. The palatability of honey for infants was investigated by Ramenghi and others in 2001, and these workers report that honey is well tolerated and significantly reduces the crying phases of babies than

sterile water[96]. In a review on the importance of honey relative to sucrose in children's nutrition, honey fed infants were found to have improved haematological profiles and calcium uptake, no digestion problem, lighter and thinner faeces, better skin colour, less susceptibility to diseases, and steady weight gain[28]. These beneficial effects produced by natural honey when included in infant formula are attributable to its effects in enhancing the gastrointestinal function which include the digestion process. The possible cause is the prebiotic effect of carbohydrate constituents, the oligosaccharides in NH on intestinal microflora of these children[80–82,93,97]. One will be doing well to children by giving them honey to replace sweets and other sugary substances they are often inclined to eat.

Other physiological processes

One of the vital processes of the body that honey has the capability to influence is the renal system. In my extensive study of the effects of dietary enrichment with honey in animal models conducted in South Africa, the renal parameters obtained are within normal physiological ranges[35]. This showed that the rodents did not suffer any obvious renal pathological trait, but rather have the potential to assess the beneficial effects derivable from honey as a functional food, with tendency to improve the renal system. This assertion aligns with the conclusion of other authors that chronic consumption of natural honey enhances renal function[98]. These Nigerian Scientists fed unprocessed honey to adult male rats for 22 weeks, and observed decrease in the rate of bile flow, increase in bile cholesterol excretion, and consequent reduction in plasma cholesterol concentration in the test rats. The explanation of these biochemical observations is that the slow rate of bile flow in these rats could facilitate improved bile secretion and cholesterol excretion, leading to hypocholesterolaemia[48]. Other workers also report the beneficial effects of honey on the renal system[23].

The influence of honey on reproductive health has also been documented. It can exert a potential influence on male reproductive function as it was seen to facilitate a healthy growth of the testes in animal models (unpublished observation, Ajibola). Other workers support this assertion of positive influence on reproductive health as shown from their experimental study in which there was significant daily increase in epididymal sperm count in adult rats, an observation suggesting that oral administration of honey may enhance spermiogenesis[99].

Conclusion

As food, honey contains all the six classes of nutrients required in a balanced diet proportionately, to the extent that if consumed daily in large quantity (70–95 g), it can go for a complete meal. The administration of honey as CAM gives high nutraceutical value to the body. This emanates from its functional influence on vital processes of the entire body system, and beneficial therapeutic effects on virtually all human ailments. In addition to the dietary enrichment with this natural product, the various health benefits derivable from honey exceed that attributable to most functional foods. The presence of several nutraceuticals, phytochemicals and other bioactive constituents, as well as unique factors such as UMF and SMIF is capable of exerting influence on the blood chemistry and body metabolism of consumers. This could enhance biochemical activities, with consequent physiological modifications within the body. This myriad of substances, factors and bioactivities in honey is attributable to its significance as a functional food.

Conflict of Interest

The author declares no conflict of interest.

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