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HONEY ADULTERATION: TYPES, DETECTION CHALLENGES, AND HEALTH IMPLICATIONS

Etienajirhevwe, O. Frank* and Awikpe, Harrison-Harriet

Chemistry Unit, Department of Science Laboratory Technology, Delta State Polytechnic, Otefe – Oghara, Nigeria.

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***Corresponding Author: Etienajirhevwe, O. Frank**

Chemistry Unit, Department of Science Laboratory Technology, Delta State Polytechnic, Otefe – Oghara, Nigeria.

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ABSTRACT

Honey is a natural supersaturated solution produced by honeybees with established nutritional and therapeutic properties, including antioxidant, anti-inflammatory, antimicrobial, and anticancer activities. Its growing global demand has made it a target for food adulteration, where cheaper sugars and syrups such as corn syrup, high-fructose corn syrup, glucose syrup, and sucrose syrup are added to increase volume and reduce cost. Adulteration occurs through direct addition of syrups, indirect feeding of bees with industrial sugars, and blending of low-quality with high-quality honey, all of which alter the chemical, biochemical, and physical properties of honey. This review outlines the types and methods of honey adulteration, highlights the difficulty in detecting sophisticated adulterants due to their similarity to natural honey constituents, and summarizes the analytical techniques used for detection. More importantly, it examines the health risks associated with consuming adulterated honey. Evidence indicates that sugar-adulterated honey can reduce antibacterial activity, elevate blood glucose and insulin levels, increase oxidative stress, and contribute to obesity, type II diabetes, cardiovascular disease, and kidney and liver damage. The findings underscore the need for stricter quality control, improved detection methods, and greater consumer awareness to protect public health and maintain trust in the honey industry. Further systematic studies are required to fully establish the long-term toxicological effects of honey adulterants.

KEYWORDS: Honey, Adulteration, Health challenge, Disease.

INTRODUCTION

Honey is known as the natural sweet substance produced by honey bees from the nectar of plants or secretions of living parts of plants. The honeybees can collect and transform it by mixing it with specific substances of their own, then deposit it, dehydrate it, and store it in the honeycomb to ripen and mature. The harvested honey from honeybees can be consumed not only as a sweetener but also as a medicine due to its therapeutic effect on human health (Fakhlaeiet al., 2020). Honey, traditionally, is used for its anti-aging properties, enhancing the immune system, killing bacteria, treatment of bronchial phlegm, and relieving a sore throat, cough, and cold. Moreover, honey represents various pharmacological properties such as anti-inflammatory, antioxidant, anti-cancer activities against breast and cervical cancer, prostate cancer and osteosarcoma (Rao et al., 2016). The therapeutic effect of honey on human health can be either oral administration or topical application. The food industry is one of the critical and fast developing industries worldwide, owing to the tremendous growth of the human population and increased interest of consumers toward the consumption of high-quality products. Moreover, it has been proven that low-quality food products and junk foods may have an adverse impact on consumers' health (Fuhrman, 2018). Food adulteration will multiple this risk since the nature of food has been altered. “Food adulteration” is described as the act of intentionally decreasing the quality of food either by adding or swapping low-quality materials or eliminating various important integrant. When the cheaper and low-grade elements are added to an original product threaten the consumer’s health, it is considered and declared “adulterated.” Honey, as one of the most common foods worldwide, also has been subjected to adulteration. Hence, its quality control and safety protocols have become the center of attention of many international committees.

Food adulteration

Food adulteration refers to the act of intentionally debasing the quality of food by either adding or replacing the food substances with undeclared alternative components, or by the removal of some valuable components. This is usually done to lower the cost or increase the bulk of a given food product (Choudhary et al., 2020). The main purpose of food adulteration is to alter the quality of food products for economic advantage. Such actions usually take place by substitution with inferior quality or less valued food and increasing the weight or volume by admixture of undeclared ingredients. The principal aim behind food substitution is to reduce raw material and manufacturing cost by incorporation of inferior compounds. The physical properties and taste of food items are modified in many ways. Adulteration with

preservatives, colorants, and artificial sweeteners are common food adulteration techniques. Among other adulterations, falsification of origin is also labeled as adulteration, as it includes false claim for superior origin (Momtazet al., 2023). There are two types of food adulterations: they include intentional or deliberate adulterations and unintentional or incidental adulterations.

Intentional adulteration is an adulteration in which food item is deliberately adulterated. It is inclusion of inferior substances having properties similar to the foods in which they are added. They are thus difficult to detect. The adulterant could be physical or biological in nature. It is done in order to promote the level of their essential nutrients after reduction of a given amount in order to increase their profit margin by several chemicals like urea, melamine and increase its volume by adding substances such as starch, flour, cane sugar, vegetable oils, water etc (Choudhary et al., 2020). Incidental adulteration is an adulteration which is due to lack of proper hygienic conditions of food products and drinks throughout production site to consumption. Accidental adulterants are pesticides residues, dropping of rodents, larvae in foods etc. Adulterated food products are responsible for mild to severe health impacts as well as financial damage. Diarrhea, nausea, allergic reaction, diabetes, cardiovascular disease, etc., are frequently observed illnesses upon consumption of adulterated food. Some adulterants have shown carcinogenic, clastogenic, and genotoxic properties (Sambuet al., 2022).

Honey

Honey is a super saturated solution or semi-solid natural product synthesized formed from nectar of flowers by honeybees (*Apis mellifera*; Family: Apidae). Honey bees collect nectar, secretion of flowers or other living parts of plants and excretions of plant sucking insects. Honey bees then transform these substances by combining with specific substances of their own (Khan et al., 2018). These are deposited, dehydrated and kept in the honey comb for ripening and maturing. Honey has been used by humans since ancient times, nearly 5500 years ago. Most ancient population, including the Greeks, Chinese, Egyptians, Romans, Mayans, and Babylonians, consumed honey both for nutritional aims and for its medicinal properties (Iftikhar et al., 2022). Honey is the only insect-derived natural product, and it has nutritional, cosmetic, therapeutic, and industrial values. Honey was utilized as a natural sweetener from ancient period since it has high level of fructose (honey is 25% sweeter than tablet sugar). Moreover, the use of honey in beverages is also increasingly popular

(Samarghandian et al., 2017). Honey is the oldest food stuff and it has been used as a major sweetener in the ancient world until sugar cane was cultivated. This is why since ancient times humankind introduced honey and honeybees with much gratitude for their value (Khan et al., 2018). Evidence indicates that honey can exert several health-beneficial effects including antioxidant, anti-inflammatory, antibacterial, antidiabetic, respiratory, gastrointestinal, cardiovascular, and nervous system protective effects (Al-Hatamlehet al., 2020; Esaet al., 2022).

Physical properties of honey

Different physical parameters like color, pH, enzyme activity, ash contents, electrical conductivity and even taste of honey varies with honeybee species, geographical origin and presence of impurities (Bodor et al., 2020). The color of honey varies from pale yellow to darkish red to black depending upon plant source. The darkness mostly occurs due to change in temperature. The tendency of granule formation is the character of honey which makes it differ from other sweeteners. Like other physical parameters, the pH of honey also indicates the purity or crudeness of honey but it depends upon the geography of the area. Moisture is the most important determinant of honey solidity. High moisture content is additionally a novel property of honey and is generally ranges from 13-20% (Jaafaret al., 2017). Like other Newtonian fluids, viscosity of honey depends upon its moisture content and temperature. At 24°C with 18.9% moisture, the viscosity of honey is approximately 9.9 psa (Faustino and Pinheiro, 2021). Beside all these properties, honey is resistant to spoilage on account of its high sucrose contents. Therefore, it was used as a preservative for other food substances.

Composition of Honey

The beneficial effects of honey are attributed to various biological bioactive components. The presence of these active compounds justifies the substantial biological benefits of honey. The percentage of all these components varies among different types of honey. In general, honey consists of more than 200 substances. It is mainly a carbohydrate product, and sugars constitute more than 90% of solids. Main sugars found in honey include glucose, sucrose, maltose, fructose, melezitose, isomaltose, maltulose, turanose, nigerose, melibiose, panose, and maltotriose. Water is the second most important component of honey. Conjointly with carbohydrates and water, honey also contains enzymes, vitamins, minerals, flavonoids, and polyphenols (Tafere, 2021). However, generally honey has a content of 80–85% carbohydrates, 15–17% water, 0.3% proteins, 0.2% ashes and minor quantities of amino-

acids, phenols, pigments and vitamins. Beside these other components are also found in minor concentration (Khan et al., 2018). Riboflavin (Vit. B2), Niacin (Vit. B3), Pantothenic acid (Vit. B5), Pyridoxine (Vit. B6), Folate (Vit. B9), and vitamin C are the major vitamins found in honey. Among minerals, potassium is the major one while calcium, magnesium, sodium, sulfur, and phosphorus are also found in a significant amount. The main enzymes found in honey include invertase (saccharase), diastase (amylase), and glucose oxidase. Non-enzymatic proteins, including glycoprotein, MRJP1, and apalbumin-1, are also found in honey, but in very minute quantities (Zammit-Young and Blundell, 2023).

Nutritional Value of Honey

The composition of honey is mainly sugars and water and base on the nutritional value of honey, this healthy natural food contains not only fructose, glucose, and water, but also trace amounts of valuable ingredients, such as flavorings, vitamins (B1, B2, B3, B5, B6, B9, C, and K), minerals (Na, Ca, K, Mg, P, Se, Cu, Fe, Mn, Cr, Zn), enzymes and antioxidant (Zawawiet al., 2021). The other constituents of honey are amino acids, antibiotic-rich inhibine, proteins, phenol antioxidants, and micronutrients (Mărgăoanet al., 2021). Honey is one of humankind's oldest food products that preserve human health and shields them from various diseases, such as cancer, a cold, sore throat, etc. (Stefaniset al., 2023). The high nutritional profile of honey with wide range of nutrients (although in minute quantities), encourages its use as food. Consumption of honey as a food or a natural sweetener can boost the human body’s energy level. Honey has high antioxidant activity and antimicrobial properties and can be used for healing wounds, treat obesity, diabetes, and cancers (Kačániová et al., 2022). Natural honey has a significant effect on reducing cholesterol (7%), triglycerides (2%), C-reactive protein (7%), and homocysteine (6%). (Olas, 2020).

Medicinal properties of honey

In addition to its nutritive value, honey possesses a wide variety of therapeutic properties. It has been used to treat several diseases since ancient times. Its most common application is for healing wounds and skin infections (Spoială et al., 2022). Honey possesses significant antibacterial, antiviral, antifungal, antioxidant, anti-inflammatory, antineoplastic, antimicrobial, anticarcinogen, antiarrhythmic, antileishmanial, antithrombotic, antiplatelet, antimutagenic, antinociceptive, antimycobacterial, antiproliferative and immune-boosting properties (Yupanqui Mieles et al., 2022; Bouali et al., 2022; Hamadou et al., 2022; Stefanis et al., 2023). It is also shown to have hypocholesterolemic, cardioprotective,

antihypertensive, hepatoprotective, gastroprotective, neuroprotective, nephroprotective, and hypoglycemic effects (Obiazi et al., 2018; Bth Jidru et al., 2020; Iftikhar et al., 2022; Zhao et al., 2018).

Honey adulterants

Low-cost sugars and commercial syrups are common substances for honey adulteration and well-known adulterants from sugar cane and sugar beet such as corn syrup (CS), HFCS, glucose syrup (GS), sucrose syrup (SS), inverted syrup (IS), and high fructose inulin syrup (HFIS) has been described (Iftikhar et al., 2022). Adulteration of honey by sugars alters the chemical and biochemical properties of honey, such as the enzymatic activity, electrical conductivity, and specific compounds contents (Soares et al., 2017). Honey adulterates are selected based on the following three factors: the specific region of origin, the economic benefits and the sugars or sweeteners accessibility.

Adulteration methods

Commercial honey adulteration is typically classified as direct, indirect, and blending. The direct addition of sugar syrups is a post-production procedure of adding certain ratios to increase honey sweetness. Direct adulteration of honey is commonly performed by the direct addition of a certain amount of sucrose syrup into the honey.

The source of sucrose syrup could be sugar beet, HFCS, maltose syrup, or industrial sugar syrups (glucose and fructose) obtained from heat, enzyme, or acid treatment of starch (Soares et al., 2017). Direct adulteration causes harm to consumers and pure honey producers. Meanwhile, indirect adulteration occurs by overfeeding the bees during the main nectar period with honey, chemicals, and industrial sugars to recover more honey from hives (Wu et al., 2017). Indirect adulteration of honey is the incorporation of sugars into honey via bee-feeding. In this manner, low-quality honey, chemicals, and industrial sugars were incorporated into the honey during a natural process that happened in the bee's digestive system. During indirect honey adulteration, an extreme amount of sugar syrup was fed to the bee colonies in the main nectar flow period. Blending is another honey adulteration procedure, which can be explained as mixing pure and high-quality honey with cheap and low-quality honey. However, the syrup or sugar residues of some reported studies are identical to the natural residues in the honey. Therefore, the detection of these adulterants has proved difficult, and scientists have to discover new methods to distinguish the differences between pure and adulterated honey (Yan et al., 2022).

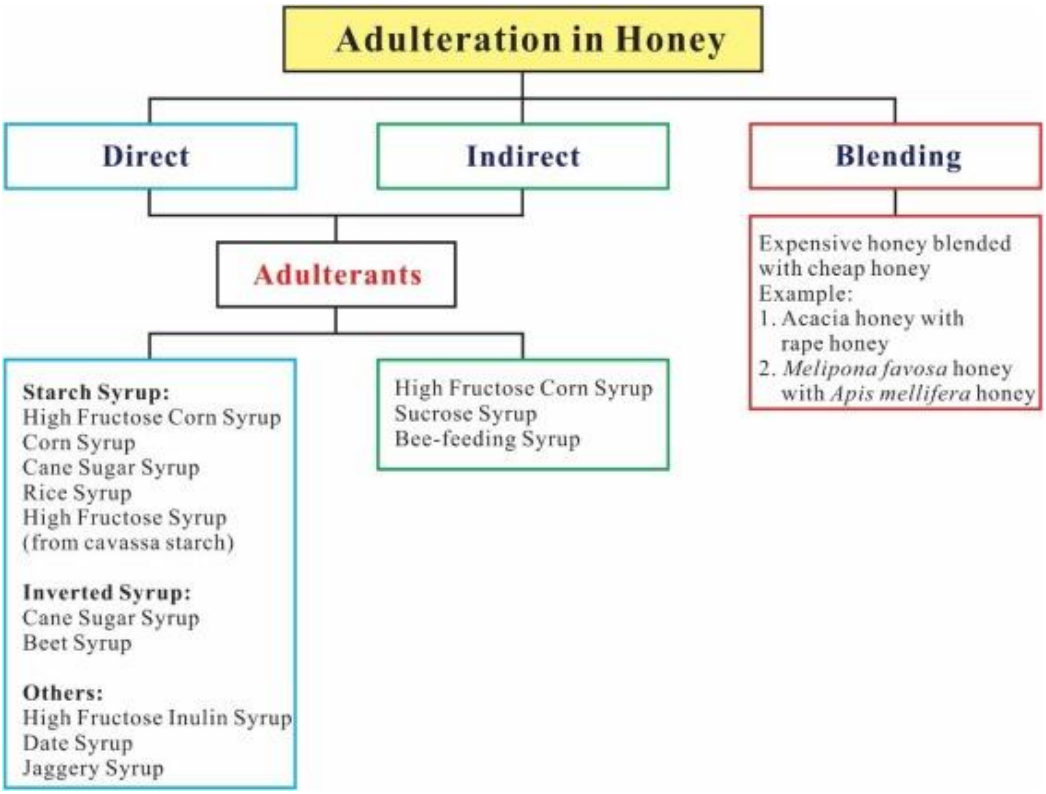
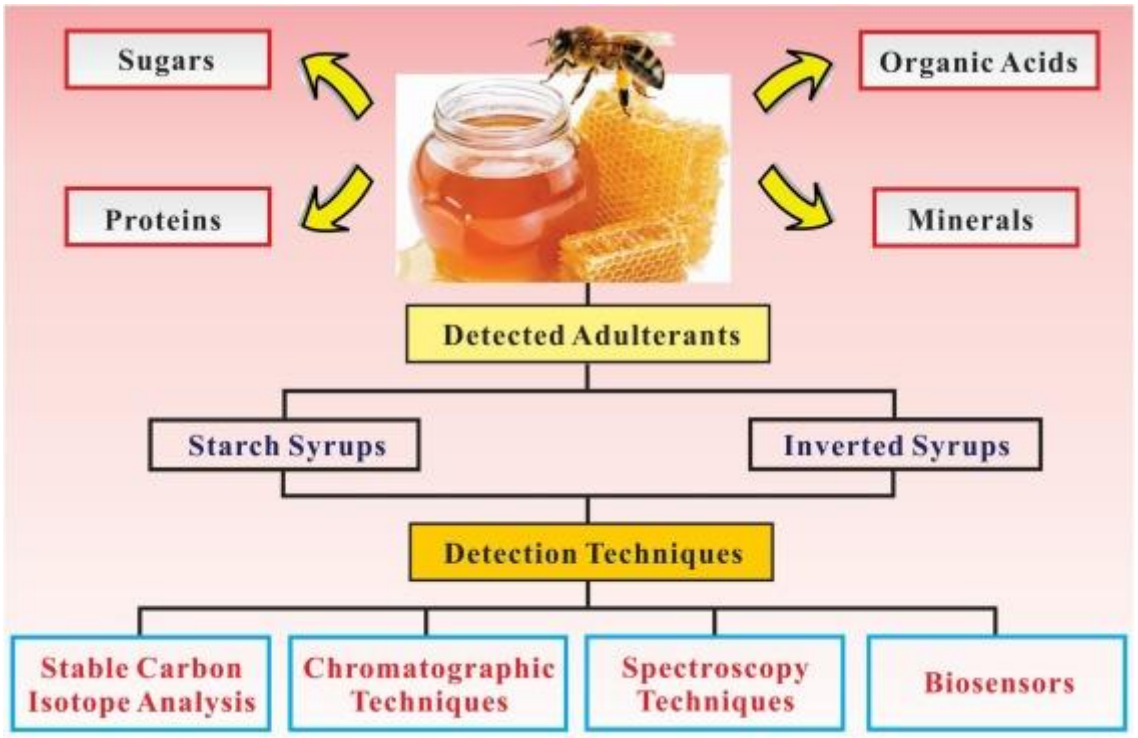


Figure 1. Various types of honey adulterations and the detected adulterants.

Source: Momtaz et al. (2023)



Scheme 1. The various types of analytical techniques used for detecting adulterants in honey.

Source: Momtaz et al. (2023)

Adverse health impact of honey adulteration

The adverse health impacts of consuming adulterated honey on human health are not completely established yet due to an absence of systematic and scientific studies and lack of public awareness.

Pure honey showed significantly lower toxicity due to containing simple sugar (glucose and fructose) and other essential nutrients such as proteins, antioxidants, and minerals. While honey has an antibacterial effect, helping to fight common cold and some digestive problems, the mixture of inverted sugar or jaggery can sometimes restrict the antibacterial properties of honey and lead to stomach disorders (Peng et al., 2020). Adulteration harms consumers' health, which may cause increased blood sugar followed by the release of the insulin hormone and type II diabetes, abdominal weight gain, and obesity, a raise in the level of blood lipid, and high blood pressure (Sammet et al., 2018). Consumption of glucose from sugar-adulterated honey may elevate insulin secretion. Insulin activates the plasma membrane enzyme system with the properties of NADPH-oxidase resulting in not only the production of H_2O_2 and fructose but also increases uric acid in humans. Adulteration of honey with glucose and fructose produce ROS through various mechanisms in the body, which is detrimental toward human health and causes chronic diseases such as atherosclerosis, diabetes, obesity, hypertension, coronary artery diseases, and finally heart failure (Sammet et al., 2018). The intake of adulterated honey cases kidney damage due to lose of kidney capability to expel creatinine and urea from the serum and prolonged consumption of HFCS would lead to glomerular filtration failure (Li et al., 2015). Natural honey possesses some beneficial effects, such as lower total cholesterol and LDL in healthy overweight human subjects, while consumption of 3 to 20% of dietary fructose caused the elevation of total cholesterol and LDL by 9% and 11%, respectively. In this regard, the addition of sugar to honey could be critical toward human health.

CONCLUSION

The significant impact of honey adulteration on market loss, reducing the quality of honey, shows the importance of studies to investigate different honey adulterants, adulteration methods, and detection methods. Moreover, this has an adverse impact on the honey production industry and market by reducing the trust of consumers on this valuable product. Adulterants have health disadvantages toward human health based on their concentration and internal organ toxicology. The kidney and liver are the main organs that fail due to the

consumption of sugar-adulterated honey. Diabetes, CKD are the direct results of honey adulteration. These diseases have a noticeable impact on human daily life and social health.

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