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Review

Honey: Chemical composition, stability and authenticity

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ABSTRACT

The aim of this review is to describe the chemical characteristics of compounds present in honey, their stability when heated or stored for long periods of time and the parameters of identity and quality. Therefore, the chemical characteristics of these compounds were examined, such as sugars, proteins, amino acids, enzymes, organic acids, vitamins, minerals, phenolic and volatile compounds present in honey. The stability of these compounds in relation to the chemical reactions that occur by heating or prolonged storage were also discussed, with increased understanding of the behavior regarding the common processing of honey that may compromise its quality. In addition, the identity and quality standards were described, such as sugars, moisture, acidity, ash and electrical conductivity, color, 5-HMF and diastase activity, along with the minimum and maximum limits established by the Codex Alimentarius.

Contents

1. Introduction . . . 310
2. Chemical composition and reaction products . . . 310
   2.1. Sugars . . . 310
   2.2. Proteins . . . 311
   2.3. Organic acids . . . 311
   2.4. Vitamins . . . 312
   2.5. Minerals . . . 312
   2.6. Phenolic compounds . . . 313
   2.7. Volatile compounds . . . 313
3. Stability of the compounds present in honey . . . 314
4. Parameters of identity and quality of honey . . . 317
   4.1. Sugars . . . 317
   4.2. Moisture and water activity (A_w) . . . 318
   4.3. Free acidity and pH . . . 318
   4.4. Ash and electrical conductivity . . . 318
   4.5. Color . . . 319
   4.6. 5-Hydroxymethylfurfural (5-HMF) . . . 319

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4.7. Diastase activity . . . 319
4.8. Physical–chemical characteristics of honeys *A. mellifera* L. from different continents . . . 321
5. Conclusions . . . 321
Acknowledgments . . . 321
References . . . 321

1. Introduction

Honey is a natural food, mainly composed of sugars and other constituents such as enzymes, amino acids, organic acids, carotenoids, vitamins, minerals, and aromatic substances. It is rich in flavonoids and phenolic acids that exhibit a wide range of biological effects and act as natural antioxidants (Alqarni, Owayss, & Mahmoud, 2012). The composition, color, aroma and flavor of honey depend mainly on the flowers, geographical regions, climate and honeybee species involved in its production, and are also affected by weather conditions, processing, manipulation, packaging and storage time (Escuredo, Dobre, Fernández-González, & Seijo, 2014; Tornuk et al., 2013).

Moreover, honey is a food that undergoes many changes in its composition during storage. Thus, these are expected changes that usually occur due to different chemical reactions, including fermentation, oxidation and thermal processing, thereby modifying honey constituents (Moreira, Maria, Pietroluongo, & Trugo, 2010). For example, 5-hydroxymethylfurfural (5-HMF), which is a *Maillard* reaction product, can be formed when honey is submitted to heat treatment or a long storage time (Tornuk et al., 2013), becoming volatile and toxic, depending on its concentration. In addition, 5-HMF can also be formed by the dehydration of sugars in an acidic environment, such as honey (Barra, Ponce-Díaz, & Venegas-Gallegos, 2010; Castro-Vázquez, Díaz-Maroto, & Pérez-Coello, 2007; Wang, Juliani, Simon, & Ho, 2009).

The limited availability and high price of honey have provided a heightened interest in its adulteration. The identity and quality parameters of honey are considered useful for detecting these possible adulterations, and also for confirming the hygiene conditions for the manipulation and storage of honey (Puscas, Hosu, & Cimpoiu, 2013).

Honey is a viscous, aromatic, sweet food that is consumed and enjoyed by people around the world. For this reason, it requires certain standards and norms that guarantee its identity and quality so that consumers may safely consume honey, and the same shall have free circulation in the internal market and access to the external market (Codex Standard for Honey, 2001). The most common forms of honey tampering are the addition of cheap sweeteners (such as cane sugar or refined beet sugar, corn syrup, high fructose or maltose syrup) and honeybees fed with sucrose (Puscas et al., 2013).

This review aims to describe the characteristics of the compounds present in honey to expand knowledge about the stability of chemical compounds in order to identify markers that could attest to the chemical stability of honey as a food and the quality safety measure for consumers. In addition, this review describes the parameters that confirm the quality and authenticity of honey and finds similar characteristics in the different honeys produced throughout the world, using requirements such as purity, maturity and deterioration, as defined by the Codex Alimentarius.

2. Chemical composition and reaction products

Honey is a food that contains about 200 substances (Escuredo, Míguez, Fernández-González, & Seijo, 2013), and consists mainly of sugars, water, and other substances such as proteins (enzymes), organic acids, vitamins (especially vitamin B6, thiamine, niacin, riboflavin and pantothenic acid), minerals (including calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc), pigments, phenolic compounds, a large variety of volatile compounds, and solid particles derived from honey harvesting (Alqarni et al., 2012; Ciulu et al., 2011; Pontes, Marques, & Câmara, 2007). In order to better understand each component present in honey and their behavior in prolonged storage, the topics listed below describe each compound present in honey, outlining their chemical structures, their importance as a structural constituent of honey and studies that show the stability of these components during storage time.

2.1. Sugars

Monosaccharides represent about 75% of the sugars found in honey, along with 10–15% disaccharides and small amounts of other sugars. The sugars present in honey are responsible for properties such as energy value, viscosity, hygroscopicity and granulation (Kamal & Klein, 2011).

Sugar composition depends mainly on the honey's botanical origin (the types of flowers used by the bees), geographical origin, and is affected by climate, processing and storage (Escuredo et al., 2014; Tornuk et al., 2013). The concentration of fructose and glucose, as well as the ratio between them, are useful indicators for the classification of monofloral honeys (Kaskoniene, Venskutonis, & Ceksteryte, 2010). In almost all types of honey, fructose is the carbohydrate in greatest proportion, except in some honeys such as rape (*Brassica napus*) and dandelion (*Taraxacum officinale*), wherein the fraction of glucose may be higher than the fraction of fructose (Escuredo et al., 2014), and consequently these honeys, generally, have a rapid crystallization.

The sugar profile of honey has been studied by scientists throughout the world. In these profiles, many sugars were detected, such as fructose, glucose, sucrose, rhamnose, trehalose, nigerobiose, isomaltose, maltose, maltotetraose, maltotriose, maltulose, melezitose, melibiose, nigerose, palatinose, raffinose, erlose and others (Fuente, Ruiz-Matute, Valencia-Barrera, Sanz, & Castro, 2011).

Sugars in honey are represented by monosaccharides, glucose and fructose, followed by disaccharides, sucrose, maltose, turanose, isomaltose, maltulose, trehalose, nigerose, kojibiose and trisaccharides maltotriose and melezitose. Disaccharides and trisaccharides like sucrose and maltotriose are hydrolyzed enzymatically to monosaccharides. Sucrose consists of one molecule of fructose linked with glucose through α-1,4 binding. It is hydrolyzed by the enzyme invertase, yielding an equimolar mixture of hexoses (Kamal & Klein, 2011).

Maltotriose consists of three glucose units (α-1,4 glycosidic bonds), which are hydrolyzed by enzymes to maltose. Maltose is also hydrolyzed by enzymes, but in this case, the enzyme is α-glucosidase, resulting in two glucose molecules (Soldatkin et al., 2013).

Sugars and other components of honey may change during storage. Rybak-Chmielewska (2007) analyzed both stabilized (at a temperature of 100 °C for 15 min – enzyme inactivated) and non-stabilized honeys stored for 24 weeks. Sucrose concentration in honeys that were not stabilized decreased 14% in honey stored at 4 °C, and 79% in honey stored at room temperature (20 °C). For