

## STUDY OF THE QUALITY OF HONEY SOLD IN THE REGION OF JUIZ DE FORA - MG<sup>1</sup>

**Antônio Francisco de Freitas<sup>2</sup>**  
**Anderson Antônio Neto da Silva**  
**Joana Darc Sousa Chaves**

### ABSTRACT

Honey production in Brazil represents a significant economic activity, with particular prominence in the Juiz de Fora region, Minas Gerais. However, honey quality can be influenced by factors such as local flora, beekeeping management, and environmental conditions. This study aimed to evaluate the physicochemical characteristics of honey sold in the region, assessing its compliance with Normative Instruction N° 11/2000. Ten commercial samples have been analyzed for reducing and non-reducing sugar contents, moisture, water-insoluble solids, minerals, diastase activity, hydroxymethylfurfural (HMF), and total acidity, according to methodologies established by the Adolfo Lutz Institute and AOAC. Three samples exhibited reducing sugars below 65%, and four exceeded 20% moisture content, indicating a risk of fermentation. Diastatic activity of three samples is possible through enzymatic manipulation. HMF levels varied between 35 and 60 mg/kg, approaching the legal limit. Total acidity exceeded 50 mEq/kg in two samples. Minerals and water-insoluble solids remained within established standards. These findings reveal deficiencies in the management, harvesting, and storage of honey commercialized in Juiz de Fora. Despite partial compliance with current legislation, the results underscore the necessity of implementing good beekeeping practices and quality control measures to ensure the safety and enhance the value of this regional product.

**Keywords:** Quality; Composition; Regulation; Storage.

## ESTUDO DA QUALIDADE DO MEL COMERCIALIZADO NA REGIÃO DE JUIZ DE FORA – MG

### RESUMO

A produção de mel no Brasil é uma atividade econômica relevante, com destaque para a região de Juiz de Fora - MG. No entanto, sua qualidade pode ser influenciada por fatores como flora local, manejo apícola e condições ambientais. Este estudo teve como objetivo avaliar as características físico-químicas do mel comercializado na região, verificando sua conformidade com a Instrução Normativa n° 11/2000. Foram analisadas 10 amostras comerciais quanto aos teores de açúcares redutores e não redutores, umidade, sólidos insolúveis em água, minerais, atividade diastásica, hidroximetilfurfural (HMF) e acidez total, conforme metodologias do Instituto Adolfo Lutz e da AOAC. Três amostras apresentaram

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<sup>2</sup>**Autor correspondente:** Antônio Francisco de Freitas, e-mail: [antoniofreitas509@gmail.com](mailto:antoniofreitas509@gmail.com).

açúcares redutores abaixo de 65%, e quatro excederam 20% de umidade, indicando risco de fermentação. A atividade diastásica de três amostras apontou possível degradação enzimática. O HMF variou de 35 a 60 mg/kg, próximo ao limite legal. A acidez total foi superior a 50 mEq/kg em duas amostras. Minerais e sólidos insolúveis permaneceram dentro dos padrões. Os achados indicam falhas no manejo, colheita e armazenamento do mel comercializado em Juiz de Fora. Apesar da conformidade parcial com a legislação, os resultados reforçam a necessidade de boas práticas apícolas e controle de qualidade, visando a segurança e valorização do produto regional.

**Palavras-chave:** Qualidade. Composição. Regulamentação. Armazenamento.

## 1 INTRODUCTION

Honey is a natural product obtained by bees from floral nectar or plant secretions, which they transform, combine with their own substances, store, and allow to mature in the hive combs (Brazil, 2000). Rich in simple carbohydrates, honey possesses nutritional and medicinal properties attributed to its composition of sugars, minerals, and enzymes (Bobis et al., 2020). When pure, it should present a liquid, dense, viscous, and translucent appearance - characteristics that reflect its origin and processing.

Brazil ranks as the tenth largest honey producer worldwide, with approximately 350,000 beekeepers and a production volume of 64,188,949 kg in 2023, representing a 2.7% increase compared to 2022 (IBGE, 2023). In spite of this, national per capita consumption is only 60 g per year, whereas the global average is 240 g, indicating potential for expansion of the domestic market.

Honey quality in Brazil is regulated by Normative Instruction No. 11/2000 of the Ministry of Agriculture, Livestock and Supply (MAPA), which establishes physicochemical standards to assess the product's identity, purity, and integrity. These parameters include: (1) maturity - reducing sugars, moisture, and apparent sucrose; (2) purity - minerals, pollen, and water-insoluble solids; and (3) deterioration - acidity, diastase activity, and hydroxymethylfurfural (HMF).

Reducing sugars, such as glucose and fructose, are the main constituents of honey. In contrast, sucrose (a non-reducing sugar) should be present at low concentrations, as elevated levels may indicate adulteration or premature harvesting (Albu et al., 2025; Da Silva, 2022). Moisture content is also a critical parameter: high values favor fermentation by yeasts and microbiological deterioration, mainly due to honey's hygroscopic nature (Živkov Baloš et al., 2023).

The presence of water-insoluble solids (such as pollen, dust, or wax fragments) may indicate environmental contamination or deficiencies in handling and extraction. Analyzing these solids allows inference regarding both the botanical origin and the hygienic-sanitary conditions of production (Ballesteros et al., 2019).

Diastase enzyme activity, contributed by bees, is another important indicator, as it goes through a degradation process over time and with heat exposure. Thus, it requires careful storage and processing to preserve honey's commercial value (Rosyidah & Andrianto, 2024).

Hydroxymethylfurfural (HMF) is a cyclic aldehyde formed from the reaction of reducing sugars in acidic media, especially during heating or improper storage. Elevated HMF levels may indicate aging, excessive pasteurization, or adulteration through the addition of inverted syrups (Sajtos et al., 2024). Additionally, toxicological concerns exist, such as cytotoxicity, mutagenicity, and carcinogenicity associated with the consumption of honey containing high levels of this compound.

Another essential parameter is total acidity, which reflects the freshness and stability of honey. High values can result from fermentation or chemical degradation, negatively affecting sensory characteristics and product acceptance (Da Silva, 2022; Schiassi et al., 2021).

Honey production plays a relevant socioeconomic role and contributes to biodiversity conservation. However, product quality can be affected by variables such as predominant flora, beekeeping management practices, and environmental conditions in the production region.

Despite extensive honey production in Minas Gerais, there is a scarcity of specific studies evaluating the physicochemical parameters of honey produced in the Juiz de Fora region. This gap justifies investigations aimed at identifying the quality of local honey against official standards, especially given the area's significant apicultural potential.

The results of this study are expected to provide support for beekeepers, regulators, and consumers, contributing to improvements in production, inspection, and the valorization of regional honey. Therefore, the objective of this work was to assess the physicochemical characteristics and quality of honey produced in the Juiz de Fora region, Minas Gerais.

## 2 METHODS

This study was characterized as a quantitative research with a descriptive design and applied nature, conducted between February and June 2025. Physicochemical analyses were performed on ten distinct honey samples, acquired from various points of sale, including supermarkets and open-air markets in the city, aiming to partially represent the diversity of products available to the local consumer. The samples were selected by convenience.

Upon acquisition, all samples were stored in their original containers in a dry and ventilated environment, protected from light, at a controlled room temperature ( $22 \pm 2$  °C) until analysis.

The following parameters were analyzed: reducing sugars (Method 038/IV) and non-reducing sugars as sucrose (Method 039/IV), according to the methodology proposed by the Adolfo Lutz Institute (2008); moisture (Method 969.38), total acidity (Method 962.19), diastase activity (Method 958.09), and hydroxymethylfurfural – HMF (Method 980.23), following the protocol established by AOAC (2019); mineral content (Method 15714-3) and water-insoluble solids (Method 15714-5), according to standards of the Brazilian Association of Technical Standards – ABNT (2009).

All laboratory analyses have been conducted in triplicate by a trained technical team using equipment calibrated in accordance with the requirements of each technical protocol.

### 2.1 Determination of Reducing and Non-reducing Sugars

Reducing sugars were determined using Fehling's method. Approximately 1.0 g of each homogenized honey sample was dissolved in 50.0 mL of distilled water and transferred to a 250.0 mL volumetric flask. Potassium ferrocyanide (15% w/v, 5.0 mL) and zinc sulfate (30% w/v, 5.0 mL) were added, the solution was completed with distilled water, and the mixture was filtered through qualitative filter paper. The filtrate was titrated against Fehling's solutions A and B under boiling conditions until color change indicated endpoint, confirmed by the disappearance of methylene blue as indicator.

For non-reducing sugars, 50.0 mL of the filtrate were transferred to a 100.0 mL volumetric flask and hydrolyzed with 2.0 mL of hydrochloric acid (P.A.) in a water bath at 60 °C for 60 minutes. After cooling, neutralization was performed with 40% w/v sodium hydroxide using a pH meter. Potassium ferrocyanide and zinc sulfate were added as previously described, and titration followed the same procedure as for reducing sugars.

Calculations were expressed in g glucose/100 g sample, applying conversion and dilution factors according to official standards.

## **2.2 Moisture**

Moisture content was obtained by refractometry at 20 °C, with values interpreted according to AOAC reference tables (2019).

## **2.3 Total Acidity**

For acidity determination, 10.0 g of honey were dissolved in 75.0 mL of CO<sub>2</sub>-free water. The sample was titrated under magnetic stirring with 0.05 mol·L<sup>-1</sup> NaOH until reaching pH 8.50, followed by controlled addition of NaOH and back-titration with 0.05 mol·L<sup>-1</sup> HCl to pH 8.30. Results were expressed as free, lactonic, and total acidity (mEq/kg).

## **2.4 Diastase Activity**

Diastase activity was measured following AOAC Method 958.09. Standardization of a 2% w/v starch solution was performed to adjust absorbance to  $0.760 \pm 0.02$  at 700 nm. The test solution was prepared immediately prior to analysis by dissolving 5.0 g of honey in water with acetate buffer and sodium chloride, adjusted to a final volume of 25.0 mL. The reaction between starch and sample was monitored at 40 °C, with aliquots withdrawn at 5-minute intervals, mixed with iodine solution, and absorbance measured at 660 nm until values fell below 0.235. Diastase activity was expressed in Goethe units, calculated from regression curves relating absorbance and reaction time.

## **2.5 Hydroxymethylfurfural (HMF)**

HMF content was determined spectrophotometrically at 284 and 336 nm. After clarification with Carrez I and II solutions, filtrates were prepared in parallel (sample and reference), the latter containing sodium bisulfite. Absorbance differences were applied in the official formula to express HMF concentration as mg/kg.

## 2.6 Mineral Content

Minerals were quantified by gravimetric incineration. Samples ( $\approx 5.0$  g) were incinerated in porcelain crucibles at  $600\text{ }^{\circ}\text{C} \pm 25\text{ }^{\circ}\text{C}$  until constant mass was achieved. Mineral content was expressed as g/100 g.

## 2.7 Water-insoluble Solids

Determination of insoluble solids was performed using a pre-dried Gooch crucible. Twenty grams of honey were diluted in hot water ( $80\text{ }^{\circ}\text{C}$ ), filtered under vacuum, and washed until free of sugars. The crucible was dried at  $135\text{ }^{\circ}\text{C}$  until constant weight, and the percentage of water-insoluble solids was calculated as g/100 g of sample.

## 2.8 Data Processing

Quantitative results were expressed as mean  $\pm$  standard deviation of triplicates. Analyses were performed using R software (version 4.3.1; R Development Core Team, 2023), employing basic functions of the Stats package. Inferential statistical tests were not applied due to the limited sample size and the non-probabilistic sampling strategy.

## 3 RESULTS AND DISCUSSION

Table 1 presents the physicochemical parameters of ten honey samples marketed in the Juiz de Fora region, Minas Gerais. The individual values for each parameter were compared against the standards established by Normative Instruction N<sup>o</sup> 11, dated from October 20, 2000, from MAPA.

The carbohydrate composition, including fructose, glucose, and sucrose, helps to determine the botanical origin of honey and is used as a classification criterion (Rosa et al., 2019; Nayik & Nanda, 2019). Reducing sugar contents ranged from 63.4 to 68.5 g/100g, with most samples meeting the minimum required threshold ( $\geq 65.0$  g/100g). However, four samples (E, F, G, and J) presented values slightly below this limit, which may indicate a lower degree of maturity or influence from the regional apicultural flora. Previous studies have reported similar variability among samples from different botanical origins (Schiassi et al., 2021; Da Silva, 2022; Da Silva, Freitas & Carneiro, 2025).

**Table 1. Compliance of Honey Samples from the Juiz de Fora Region– MG with the Parameters of Normative Instruction N° 11/2000.**

| Parameter                          | IN n°<br>11/2000 | Samples       |               |           |               |           |           |               |               |               |           |
|------------------------------------|------------------|---------------|---------------|-----------|---------------|-----------|-----------|---------------|---------------|---------------|-----------|
|                                    |                  | A             | B             | C         | D             | E         | F         | G             | H             | I             | J         |
| Reducing Sugars<br>(g/100g)        | ≥ 65.0           | 66.3±1.5      | 66.7±0.6      | 68.5±1.2  | 67.8±1.0      | 63.4±0.8  | 64.7±0.6  | 63.5±1.3      | 65.1±0.3      | 65.5±0.5      | 64.6±0.5  |
| Non-Reducing<br>Sugars (g/100g)    | ≤ 5.0            | 4.2±0.4       | 3.4±0.5       | 4.3±0.3   | 2.4±0.4       | 4.9±0.2   | 4.4±0.5   | 4.2±0.6       | 4.3±0.4       | 4.7±0.3       | 4.6±0.7   |
| Moisture (g/100g)                  | ≤ 20.0           | 17.6±1.5      | 15.0±2.0      | 20.0±1.0  | 17.3±1.5      | 21.3±0.6  | 21.7±0.6  | 22.7±0.6      | 18.3±0.6      | 19.7±0.6      | 20.7±0.6  |
| Water-Insoluble<br>Solids (g/100g) | ≤ 0.1            | 0.08±0.0<br>1 | 0.08±0.0<br>1 | 0.08±0.02 | 0.06±0.0<br>2 | 0.08±0.02 | 0.07±0.03 | 0.07±0.0<br>1 | 0.08±0.0<br>2 | 0.08±0.0<br>1 | 0.06±0.02 |
| Minerals (g/100g)                  | ≤ 0.6            | 0.4±0.1       | 0.4±0.2       | 0.5±0.2   | 0.5±0.1       | 0.4±0.2   | 0.5±0.2   | 0.6±0.2       | 0.5±0.2       | 0.5±0.2       | 0.6±0.2   |
| Diastase Activity<br>(Göthe)       | ≥ 8.0            | 11.0±1.0      | 13.7±1.2      | 8.7±0.6   | 9.7±1.5       | 7.3±0.6   | 7.7±0.6   | 7.3±0.6       | 9.3±0.6       | 8.0±0.1       | 8.3±0.6   |
| Hydroxymethylfurfur<br>al (mg/kg)  | ≤ 60.0           | 15.3±1.5      | 17.7±2.1      | 40.7±2.1  | 21.7±2.5      | 57.0±1.0  | 51.7±1.5  | 54.3±0.6      | 38.7±0.6      | 49.0±1.0      | 48.5±0.5  |
| Total Acidity<br>(mEq/kg)          | ≤ 50.0           | 30.7±1.5      | 31.0±1.0      | 44.0±3.0  | 35.3±1.2      | 50.7±0.6  | 50.6±0.5  | 49.7±0.6      | 40.0±1.0      | 41.0±1.0      | 47.5±0.5  |

Source: The authors, 2025.

Water is the second largest component of honey and directly influences its flavor, viscosity, stability, and fermentation potential. Moisture contents ranged from 15.0 to 22.7 g/100g, with four samples (E, F, G, and J) exceeding the regulatory limit ( $\leq 20.0$  g/100g), suggesting premature harvesting or inadequate storage - factors that increase microbiological susceptibility (Wilde, 2013; Mesele, 2021).

Determining water-insoluble solids allows the assessment of impurities such as wax, hairs, bee wings, and pollen grains, serving as an important indicator of the product's hygienic-sanitary conditions (Ballesteros et al., 2019). All samples presented values below the 0.1 g/100g threshold, indicating appropriate centrifugation and filtration during processing.

Mineral content ranged from 0.4 to 0.6 g/100g, within the legal limit of 0.6 g/100g. Mineral concentration in honey may be associated with soil and environmental characteristics; however, elevated values could indicate contamination from inappropriate utensils or environmental pollution (Da Silva, 2022; Živkov Baloš et al., 2023).

Diastase activity varied between 7.3 and 13.7 Göthe units. Three samples (E, F, and G) fell below the established limit (8.0 Göthe), indicating enzymatic degradation possibly caused by excessive heating or prolonged storage. Similar studies in Minas Gerais have also linked low diastase activity to inadequate transportation and storage conditions (Da Silva, Freitas & Carneiro, 2025).

Hydroxymethylfurfural (HMF) levels ranged from 15.3 to 57.0 mg/kg, remaining below the limit of 60.0 mg/kg. Sample E, with a value near the limit, may have been exposed to high temperatures during processing or storage. According to Godoy, Valderrama & Boroski (2022), HMF is sensitive to temperature and packaging conditions, serving as an important indicator of degradation.

Comparable results were found by Sęk, Porębska & Szczęśna (2023) in their analysis of commercial samples in Poland: many samples exhibited low diastase activity but not elevated HMF levels, suggesting different causes for enzymatic degradation.

Regarding total acidity, it varied from 30.7 to 50.7 mEq/kg. Two samples (E and F) showed values slightly above the limit (50.0 mEq/kg), possibly due to fermentative processes or degradation of organic compounds (Karabagias et al., 2017). Elevated acidity may compromise the sensory profile of honey, directly impacting its commercial acceptance (Schiassi et al., 2021).

Studies indicate that consumer perception is directly related to perceived quality, involving freshness, packaging and product safety (Nascimento et al., 2022). Ensuring honey's compliance with normative standards not only guarantees food safety but also strengthens its competitiveness in national and international markets.

#### 4 CONCLUSION

The analysis of the physicochemical characteristics of honey produced in the Juiz de Fora region, Minas Gerais, revealed that although most samples comply with Normative Instruction N° 11/2000, inconsistencies were identified that may compromise the quality and commercial viability of the product.

Three samples exhibited reducing sugars below the regulatory limit, possibly influenced by local flora or premature harvesting. Four samples showed moisture levels exceeding the permitted threshold, increasing the risk of fermentation and microbiological instability. Enzymatic degradation, indicated by low diastase activity, pointed to deficiencies in storage conditions. Although HMF contents remained within limits, one sample approached the critical value, highlighting the need for more effective thermal control. Additionally, two samples with elevated total acidity may face sensory rejection by consumers, compromising market acceptance.

Given these results, improvements in harvesting, storage and processing practices are recommended to ensure the stability and compliance of honey. Training producers, combined with inspection of production and marketing conditions, can significantly contribute to enhancing the value of regional honey and strengthening its competitiveness in national and international markets.

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## DADOS DOS AUTORES:

### **Antônio Francisco de Freitas**

**E-mail:** [antoniofreitas509@gmail.com](mailto:antoniofreitas509@gmail.com)

**Curriculum Lattes:** <http://lattes.cnpq.br/9955142590505719>

Possui graduação em Farmácia pelo Centro Universitário Presidente Antônio Carlos(2025), curso-tecnico-profissionalizante em Técnico em leites e Derivados pela EPAMIG Instituto de Laticínios Cândido Tostes(2019) e ensino-medio-segundo-graupela Escola Estadual Ministro Clóvis Salgado(2015). Atualmente é Responsável Técnico substituto da BrQuality Consultoria e Laboratório. Tem experiência na área de Farmácia, com ênfase em Farmácia clínica, assistência e atenção farmacêuticas.

### **Anderson Antonio Neto da Silva**

**E-mail:** [andersonantonio1227@gmail.com](mailto:andersonantonio1227@gmail.com)

**Curriculum Lattes:** <http://lattes.cnpq.br/0668220571255465>

Graduado em Tecnologia em Alimentos pelo Instituto Federal do Sudeste de Minas Gerais Campus Barbacena (2021), especialização em Gestão da Segurança de Alimentos pelo Centro

Universitário Senac (2023) e mestre em Ciências dos Alimentos (2026) na Universidade Federal de Lavras (UFLA). Atua nas áreas de comportamento do consumidor e pesquisa de mercado, com ênfase na investigação de fatores que influenciam a percepção, aceitação e preferência dos consumidores. Desenvolve pesquisas qualitativas e quantitativas voltadas ao mapeamento de tendências, identificação de oportunidades de inovação, definição de conceitos de produtos e avaliação do potencial de mercado de novos alimentos.

**Joana Darc Souza Chaves**

**E-mail:** [joanachaves@unipac.br](mailto:joanachaves@unipac.br)

**Curriculum Lattes:** <http://lattes.cnpq.br/6250394384770679>

Possui graduação em Licenciatura Plena Em Química pela Universidade Federal de Juiz de Fora (2002), graduação em Bacharelado Em Química pela Universidade Federal de Juiz de Fora (2002), mestrado em Química pela Universidade Federal de Juiz de Fora (2004) e doutorado em Química pela Universidade Federal de Juiz de Fora (2014). Atualmente é professora da Escola Estadual Ali Halfeld e professora do Centro Universitário Presidente Antônio Carlos. Tem experiência na área de Química, com ênfase em Síntese Orgânica, química inorgânica, química geral, físico-química e na área ambiental com ênfase em Gestão de resíduos sólidos domésticos e industriais, de tratamentos biológicos e físico-químicos de efluentes e química ambiental.