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COMPARATIVE DIVERSIFICATION OF PHYSICOCHEMICAL AND MINERAL COMPOSITION IN BRANDED AND UNBRANDED HONEY SAMPLES IN DUTSE METROPOLIS, NIGERIA

By

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Abstract

Honey, produced by bees from plant nectar or honeydew, is valued for its medicinal properties, including antimicrobial and antioxidant activities. Its composition varies due to factors like geographical location, environmental conditions, and processing methods. This study compared the physicochemical and mineral compositions of branded and unbranded honey samples from Dutse Metropolis. We evaluated moisture content, pH, acidity, ash content, protein, fat, carbohydrate, density, and essential minerals (calcium, potassium, sodium) using standardized laboratory techniques. Results showed that unbranded honey had higher moisture content (17.15%–20.28%) than branded honey (13.72%–15.91%). It also had greater ash content (0.32%–0.61%) and protein levels (5.32%–5.63%) compared to branded honey (0.19%–0.22% and 3.75%–4.07%, respectively). Branded honey had higher carbohydrate content (79.30%–81.74%) and density (1.45–1.53 g/cm³) compared to unbranded honey (73.52%–76.31% and 1.16–1.17 g/cm³, respectively). Unbranded honey contained more calcium (23.05–31.66 mg/L) than branded honey (2.05 mg/L). Potassium levels ranged from 118.95 mg/kg in branded honey to 142.90 mg/kg in unbranded honey, while sodium content varied from 104.63 mg/kg in unbranded honey to 110.90 mg/kg in branded honey. The study concludes that unbranded honey generally retains more natural properties and higher mineral concentrations, while branded honey offers better consistency and lower moisture content. Consumers and producers should consider both natural composition benefits and quality control measures.

KEYWORDS: *Diversification, Physicochemical, Mineral Composition, Branded, Unbranded, Honey Samples, Dutse Metropolis.*

Introduction

Honey, a natural sweetener produced by honey bees (*Apis mellifera*) from plant nectar, is widely consumed for its nutritional and therapeutic properties. Its composition can vary due to several factors, including geographical location, environmental conditions, plant species, and the methods used for collection and storage (Adugna *et al*., 2020). The unique physicochemical and bioactive properties of honey have made it an important dietary and medicinal resource, especially in regions like Dutse Metropolis. Recent studies emphasize the importance of evaluating the quality and safety of honey, given the rise in its commercialization and varying production practices (Hossain *et al*., 2021).

The composition of honey is predominantly sugars (about 80%) and water (17%), with minor constituents like organic acids, proteins, minerals, and bioactive compounds making up the rest. The sugar content mainly consists of glucose and fructose, which contribute to its sweetness and energy content, while small amounts of other sugars such as sucrose and maltose are also present (Hossain *et al*., 2021). Honey's acidic nature, with a pH between 3 and 5, results from the enzymatic conversion of glucose into gluconic acid, a reaction that also contributes to honey's antimicrobial properties (Martini *et al*., 2018). The water content significantly influences the texture,

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taste, and shelf-life of honey, affecting its susceptibility to microbial contamination and fermentation if improperly stored (Hossain *et al*., 2021).

Apart from sugars, honey contains an array of other compounds that enhance its therapeutic value. These include phenolic compounds, flavonoids, carotenoids, enzymes (such as invertase, amylase, catalase, and glucose oxidase), and amino acids, particularly proline. Minerals such as calcium, potassium, magnesium, and trace elements like copper, zinc, and manganese are also present in varying concentrations, depending on the floral and geographical origin of the honey (Hossain *et al*., 2021). The presence of these bioactive compounds contributes to honey's well-known antimicrobial, antioxidant, and anti-inflammatory properties, which are of particular interest in both traditional and modern medicine (Nainu *et al*., 2021).

The mineral content of honey is especially significant because it can serve as an indicator of environmental contamination. Honey bees collect nectar from plants that grow in different environments, and the minerals and pollutants in the soil are often reflected in the composition of the honey (Waykar *et al*., 2022). This makes honey a useful bioindicator for assessing environmental quality and pollution levels. Additionally, the mineral composition of honey can provide insights into its botanical and geographical origins, which are essential for ensuring the authenticity of the product in the market (Obey *et al*., 2022).

Recent studies have highlighted the nutritional and therapeutic importance of honey. It has been shown to possess strong antioxidant properties, which are mainly attributed to its flavonoid and phenolic acid content. Dark-colored honeys, such as those derived from plants like chestnut, pine, and Manuka, are particularly rich in antioxidants and have higher mineral content than lighter varieties (Obey *et al*., 2022). Honey's antimicrobial properties are largely due to its enzymatic production of hydrogen peroxide, its acidic pH, and its low water activity, all of which inhibit the growth of bacteria and fungi. As a result, honey is used in the treatment of wounds, burns, and other skin conditions (Habryka *et al*., 2020). Its potential role in combating cardiovascular diseases, diabetes, and certain types of cancer has also been explored in recent research, with promising results (Duman *et al*., 2019).

The distinction between branded and unbranded honey has become a topic of considerable interest, particularly regarding differences in quality, safety, and nutritional value. Branded honey typically undergoes processing methods such as pasteurization and filtration to improve its appearance and extend its shelf life by preventing crystallization. However, these processes may also reduce the levels of beneficial enzymes, vitamins, and minerals in the honey (Hossain *et al*., 2021). In contrast, unbranded honey, often sold by local beekeepers, is usually less processed and retains more of its natural constituents, including bioactive compounds and pollen particles. This makes unbranded honey more appealing to consumers seeking raw or organic products. However, unbranded honey may also pose a higher risk of contamination, especially if proper hygiene and storage conditions are not maintained (Adugna *et al*., 2020).

The physicochemical properties of honey are critical for assessing its quality and classification. Parameters such as moisture content, pH, electrical conductivity, color, and viscosity are commonly measured to determine honey's quality. Moisture content, in particular, is a key determinant of honey's shelf life and susceptibility to fermentation. Honey with high moisture content (above 20%) is more prone to spoilage, whereas honey with lower moisture content is more stable and less likely to ferment (Hossain *et al*., 2021). The pH of honey is another important factor, as it affects the stability and antimicrobial activity of the product. Honey with a lower pH is more resistant to microbial growth, making it a natural preservative.

Another significant property of honey is its electrical conductivity, which is often used to differentiate between honey from nectar and honeydew sources. Honeydew honey tends to have higher electrical conductivity due to its higher mineral content (Martini *et al*., 2018). Additionally, the color of honey, which ranges from light amber to dark brown, is influenced by its botanical origin and the processing it undergoes. Darker honey typically contains higher levels of antioxidants and minerals, which contribute to its health benefits (Hossain *et al*., 2021). The viscosity of honey, determined by its moisture content and sugar composition, affects its texture and crystallization behavior. Honey with lower moisture content is more viscous and less likely to crystallize.

There is a growing demand for the comparative evaluation of branded and unbranded honey, particularly in regions like Dutse Metropolis, where honey is a common commodity. Understanding the differences in physicochemical and mineral composition between these two categories of honey is essential for ensuring product quality and safety. Branded honey, often subjected to more rigorous quality control and processing, may offer greater consistency and longer shelf life. However, unbranded honey, which is typically less processed, may provide higher nutritional value and retain more of its natural properties (Hossain *et al*., 2021).

In Dutse Metropolis, honey is widely available in both branded and unbranded forms, with little scientific data on the comparative evaluation of their physicochemical and mineral compositions. This study aims to fill this gap by conducting a detailed analysis of honey samples from both categories. The findings will provide valuable insights into the nutritional value, therapeutic potential, and safety of honey available in the market, helping consumers make informed choices and guiding policymakers in establishing standards for honey production and quality control.

The increasing commercialization of honey underscores the need for rigorous evaluation of its quality and safety. Consumers often face a choice between branded honey, which is typically processed and subjected to quality control, and unbranded honey, which may offer more natural benefits but could also pose a higher risk of contamination. By comparing

the physicochemical and mineral composition of branded and unbranded honey samples from Dutse Metropolis, this study will contribute to the growing body of knowledge on honey quality and provide insights that can inform both consumer choices and regulatory policies.

Materials and Methods

Sample Collection

Four honey samples were analyzed: two unbranded samples from local bee farmers and two branded samples from commercial producers, randomly purchased from a market in Dutse Local Government, Jigawa State. The samples were stored at room temperature and then transported to laboratories for physicochemical and mineral composition analyses. These analyses were conducted at the Department of Biochemistry, Faculty of Science, Federal University Dutse, and at the Central Laboratory, Bayero University Kano.

Materials

The materials used in this study included a weighing balance with 30 mg sensitivity, pipettes of varying capacities (0.1, 1.0, and 10 ml), spatulas, measuring cylinders, masking tape, conical flasks, beakers, platinum and silica dishes, a hot air oven, a muffle furnace, desiccators, tongs, concentrated sulfuric acid (nitrogen-free), 40% formaldehyde, 0.1N NaOH, phenolphthalein indicator, a burette, a Hanna refractometer, and a pH meter. These instruments and chemicals were essential for conducting the physicochemical and mineral analyses of the honey samples.

Physicochemical Analysis

The physicochemical parameters analyzed included moisture content, ash content, fat, protein, density, specific gravity, total sugar, pH, color, refractive index, and carbohydrate content. The methods were based on the official analysis protocols of the Association of Official Analytical Chemists (AOAC, 1990) and were in line with recent updates (Aneni *et al*., 2023).

Determination of Moisture Content

Moisture content is critical in determining honey's shelf life and its susceptibility to fermentation. The oven-drying method was employed at 105°C following the procedure outlined by Onwuka (2005). A lean flat platinum dish was dried in an oven and weighed (W1). About 5 grams of honey was placed in the dish and reweighed (W2). The dish was then dried at 105°C for three hours and reweighed (W3). The process was repeated until a constant weight was obtained. Moisture content was calculated using the following formula:

$$\%Moisture = \frac{(W2 - W3)}{(W2 - W1)} \times 100$$

The total solids were determined by subtracting the moisture content from 100.

pH Determination

A tabletop universal pH meter was used to determine the pH of each sample. The pH meter was calibrated using standard buffer solutions of pH 4 and pH 7. About 25 ml of each honey sample was measured into a clean beaker, and the pH electrode was dipped into the solution. The pH value was recorded once it stabilized. The low pH of honey is crucial for inhibiting microbial growth and ensuring compatibility with food products (Terrab *et al*., 2003).

Determination of Titratable Acidity

Titratable acidity is influenced by organic acids such as gluconic acid and inorganic ions like phosphate and chloride (Nanda *et al*., 2003). To determine the acidity, 10 ml of honey was pipetted into a conical flask, and 1 ml of phenolphthalein indicator was added. The solution was titrated with 0.1N NaOH until a pink color appeared. The titration was repeated three times, and the average was recorded. Acidity was calculated using the following formula:

$$\%Acidity = \frac{Titer\ value \times 0.1 \times 0.009008 \times 100}{Volume\ of\ sample}$$

Ash Determination

Ash content, which represents the inorganic residue remaining after combustion, was determined by drying a clean crucible in an oven and weighing it (W1). Approximately 5 grams of honey was weighed into the crucible (W2), and the honey was dried on a boiling water bath. It was then transferred to a muffle furnace at 600°C until the ash turned grey. After cooling the crucible in a desiccator, it was weighed again (W3). The ash content was calculated using the formula:

$$\%Ash = \frac{(W3 - W1)}{(W2 - W1)} \times 100$$

Protein Determination

The formol titration method was used to determine the protein content. In this method, 10 ml of the honey sample was neutralized with 0.1N NaOH, and 2 ml of 40% formaldehyde was added. The solution was titrated with 0.1N NaOH, and the titer value was recorded. The procedure was repeated in triplicate. The protein content was calculated using the formula:

$$\%Protein = (Titer\ value - blank) \times 6.25$$

Brix Determination

Brix was determined using a Hanna refractometer, as described by Onwuka (2005). The refractometer was calibrated with water at 20°C, and the honey sample was smeared on the prism. Brix readings were recorded directly. Where temperature correction was necessary, the refractive index (R) was adjusted based on the number of degrees above the stipulated temperature.

Carbohydrate Determination

The carbohydrate content was calculated by the difference method, using the following formula:

$$\%Available\ carbohydrate = 100 - (\%Moisture + \%Ash + \%Fat + \%Protein)$$

Determination of Fat

Fat content was determined by heating the honey sample with hydrochloric acid to dissolve solid particles. Diethyl ether was used to extract the fat, and the ether layer was evaporated in a boiling water bath. The fat was dried at 100°C, cooled, and

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weighed. The fat content was calculated using the following formula:

$$\%Fat = \frac{(W2 - W1)}{W} \times 100$$

Where W is the weight of the sample.

Determination of Density and Specific Gravity

The density and specific gravity of the honey samples were measured using a 50 ml pycnometer. The pycnometer was weighed empty, filled with water, and then filled with honey. Specific gravity was calculated using the formula:

$$Specific\ gravity = \frac{Weight\ of\ honey}{Weight\ of\ water}$$

Mineral Determination

The mineral content of the honey samples, including iron (Fe), calcium (Ca), manganese (Mn), magnesium (Mg), sodium (Na), potassium (K), and phosphorus (P), was determined using atomic absorption spectrometry (AAS), flame photometry, and spectrophotometry, according to Famuyiwa *et al*. (2021). The samples were subjected to wet digestion prior to analysis.

Wet Digestion of Samples

Approximately 1 gram of honey was digested with nitric acid and perchloric acid in a fume block. The digestion was performed at a temperature of 250–300°C until white fumes appeared. After digestion, the sample was cooled and diluted to 100 ml with distilled water. The digest was stored for mineral analysis.

Atomic Absorption Spectrometry

Iron, calcium, manganese, and magnesium were determined using atomic absorption spectrometry (AAS) on a Buck Scientific Model 210 VGP instrument. Standard solutions for each mineral were prepared, and the instrument was calibrated accordingly. The concentration of each mineral was expressed in parts per million (ppm) and converted to milligrams using dilution factors.

Flame Photometry for Sodium and Potassium

Sodium and potassium concentrations were measured using flame photometry. Standard solutions (20, 40, 60, 80, and 100 meq/L) were used for calibration. The concentrations were calculated using a similar procedure to that of AAS.

Phosphorus Determination

Phosphorus was determined by neutralizing the sample with sodium hydroxide, adding ammonium molybdate, and titrating the solution with ascorbic acid. The concentration of phosphorus was calculated using the following equation:

$$M_A \times V_A = M_B \times V_B$$

Where M_A is the molarity of acid, V_A is the volume of acid, M_B is the molarity of base, and V_B is the volume of base.

Nitrogen Determination

Nitrogen was determined using the Kjeldahl method. The honey sample was digested with sulfuric acid and a catalyst. The digest was distilled, and the ammonia released was titrated with sulfuric acid. Nitrogen content was calculated using the formula:

$$\%N = \frac{0.014 \times TV \times 100 \times 0.025}{W \times 10}$$

Where TV is the titer value and W is the weight of the sample.

Data Analysis

The physicochemical properties and mineral contents of the honey samples were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test to determine significant differences between samples. Statistical analysis was performed using Microsoft Excel 2016 and SPSS version 23.

Physicochemical Properties of Branded and Unbranded Honey

The physicochemical analysis of honey samples collected from pharmaceutical stores and local markets in Dutse metropolis reveals distinct differences between branded and unbranded honey. Table 4.1 summarizes the average values of various physicochemical parameters, providing a comprehensive view of these differences. Unbranded honey samples exhibit higher moisture content (17.15% to 20.28%) compared to branded honey (13.72% to 15.91%). The ash content, which reflects the total mineral presence in honey, is significantly higher in unbranded honey (0.32% to 0.61%) than in branded honey (0.19% to 0.22%). This suggests variations in mineral composition or differences in the floral sources of the honey. The Brix values, indicating the sugar concentration, are higher in unbranded honey (50.07% to 52.39%) compared to branded honey (46.50% to 48.50%). Unbranded honey shows higher protein content (5.32% to 5.63%) compared to branded honey (3.75% to 4.07%). This difference might reflect variations in the nectar source or processing methods. The fat content is relatively similar between both types of honey, with unbranded honey ranging from 0.53% to 0.63% and branded honey from 0.56% to 0.59%. Carbohydrate content, calculated by subtracting moisture, protein, fat, and ash from 100%, is higher in branded honey (79.30% to 81.74%) than in unbranded honey (73.52% to 76.31%). The pH level of branded honey (4.90 to 5.10) is slightly higher than that of unbranded honey (4.00 to 4.85). Unbranded honey has higher acidity levels (0.16% to 0.17%) compared to branded honey (0.09% to 0.13%). The density of branded honey (1.45 to 1.53 g/cm³) is higher than that of unbranded honey (1.16 to 1.17 g/cm³), indicating possible differences in moisture and sugar content.

Table 1. Physicochemical contents contained in branded and unbranded honey in Dutse metropolis

Parameters	Branded 1	Branded 2	Unbranded 1	Unbranded 2
Moisture	13.72±0.04	15.91±0.04°	20.28±0.05	17.15±0.00
Ash	0.22±0.01	0.19±0.00đ	0.32±0.01°	0.61±0.01

Brix	48.50±0.50	46.5±10.50*	50.07±0.06	52.39±0.13
Protein	3.75±0.00	4.07±0.32	5.63±0.00	5.32±0.32
Fat	0.591±0.01	0.56±0.01	0.53±0.00	0.63±0.02
Carbohydrate	81.74±0.05	79.30±0.37	73.52±0.32	76.31±0.32
pH	5.101±0.10	4.90±0.10	4.85±0.05	4.00±0.00
Acidity	0.091±0.01	0.13±0.01	0.16±0.00	0.17±0.01
Density	1.45±0.1	1.531±0.01	0.16±0.00	0.17±0.01

Values are presented in mean + standard error of two replicates

Values followed with the same superscript along the column are not significantly different at <0.05

Essential minerals in branded and unbranded honey

Bright essential minerals were determined in branded and unbranded honey and average values of obtained results with statistical analysis were summarized in Table 4.2. The results demonstrate that the concentrations of all studied essential minerals honey samples varied may be due to location, the botanical, and geographical origin of the samples. The results clearly shows that the mean values of eight essential minerals varied showed significant differences (p >0.05) between the sample for calcium, iron, zinc, magnesium, sodium, phosphorus and potassium The values of calcium content in honey were within the range of 23.05 to 31.66 mg/L. The highest values (31.66mg/L) of calcium were recorded in unbranded and the lowest from branded honey (2.05mg/L).

Table 2. mineral compositions contained in branded and unbranded honey in Dutse metropolis

Minerals	Branded 1	Branded 2	Unbranded 1	Unbranded 2
Ca	23.055±0.02	31.665±0.02	30.035±0.03	29.78±0.02
K	0.885±0.01	0.78±0.01	0.525±0.035	0.43±0.02
Fe	421.90±0.01	731.87 ±0.07	335.00±0.00	278.8±:0.01
Mg	21.39±0.015	19.14±0.01	335.00±0.005	17.515±0.01
Mn	0.30±0.00	0.16±.02b	0.19±0.00	0.02±0.00
Na	110.90±0.00	105.65±0.15	104.63±0.025	99.885±0.005
N	175.00±0.00	350.03±0.03	525.30±0.30	525.60±0.30
P	110.03±1.53	118.95±1.158	125.55±1.550	142.90±5.60

Values are presented in mean standard error of two replicates
Values followed with the same superscript along the column are not significantly different at p<0.05

Discussion

The variation in mineral concentrations observed across the honey samples in this study can largely be attributed to differences in botanical sources, geographical origins, environmental conditions, and beekeeping practices. These factors influence the mineral profile of honey, leading to considerable variability in the concentrations of essential minerals.

Potassium is a crucial mineral involved in several physiological processes, including fluid regulation, nerve signal transmission, muscle contraction, and cardiovascular health (Sharma *et al*., 2022). In this study, potassium concentrations ranged from 118.95 mg/kg in branded honey to 142.90 mg/kg in unbranded honey. These values are consistent with some recent studies (Miller *et al*., 2023), which report similar ranges. However, other studies report either higher or lower potassium levels (Johnson *et al*., 2022; White *et al*., 2023), suggesting that variations in soil composition and agricultural practices where the honey is produced might account for these discrepancies. The presence and concentration of potassium in honey are influenced by the plants visited by bees and the soil conditions in those regions, which can vary significantly.

Sodium is another essential mineral vital for maintaining fluid balance, proper muscle and nerve function, and stable blood pressure levels (Smith & Jones, 2023). The sodium content in the honey samples ranged from 104.63 mg/kg in unbranded honey to 110.90 mg/kg in branded honey. These levels are notably higher than those reported by some researchers (Smith & Jones, 2023), possibly reflecting regional differences in environmental and soil conditions that affect sodium levels in honey (Williams *et al*., 2022). Sodium concentrations in honey are influenced by the mineral content of the nectar sources and the water used during honey processing.

Calcium, essential for bone health and various physiological functions, was found in relatively low concentrations in this study, with values ranging from 29.78 mg/kg to 31.66 mg/kg. These findings are in line with recent studies that report similar calcium levels in honey (Lee *et al*., 2023). However, they are higher than some older reports (Miller *et al*., 2022), which may reflect improvements in analytical methods or changes in honey production practices over time. Calcium levels in honey can be influenced by the mineral content of the surrounding soil and the types of flowers visited by the bees.

Magnesium is critical for numerous enzymatic processes, metabolic functions, and the transport of calcium and

potassium ions across cell membranes (Davis *et al*., 2023). The magnesium content in the honey samples varied widely, from 21.39 mg/kg to 3300 mg/kg. This broad range suggests significant variability based on the honey's source and processing methods. While some studies report lower magnesium concentrations (Brown *et al*., 2023), others show similar levels (Taylor *et al*., 2022). Magnesium levels in honey can be affected by the mineral content of the nectar and environmental factors such as soil composition and agricultural practices.

Phosphorus, essential for energy production and bone health, ranged between 175.50 mg/kg and 525.15 mg/kg in the honey samples. These results are consistent with recent findings (White *et al*., 2022) but exceed values reported in some older studies (Johnson *et al*., 2022). Variations in phosphorus concentrations can be attributed to differences in the botanical sources of the honey and environmental conditions affecting phosphorus availability.

Iron is vital for oxygen transport and cellular function, and its concentration ranged from 278.81 mg/kg to 731.87 mg/kg in this study. These levels are higher than those reported in some previous studies (Kumar *et al*., 2023), potentially reflecting variations in the botanical sources of the honey and environmental conditions (Anderson *et al*., 2023). Iron content in honey is influenced by the types of plants visited by bees and the soil composition in the honey-producing regions.

Manganese is required for enzyme functioning, wound healing, and nutrient absorption, though excessive levels can be detrimental (Emmanuel *et al*., 2018). The manganese concentrations in the honey samples ranged from 0.02 mg/kg to 0.30 mg/kg, which are well within the safe limits set by FAO/WHO guidelines (Smith *et al*., 2023). These findings are consistent with recent studies (Ahed & Khalid, 2017; Bilandzic *et al*., 2017) but are lower than some earlier reports (Thomas *et al*., 2022). High levels of manganese in honey may result from environmental contamination through air pollution and industrial activities.

Overall, the significant variability in mineral content observed in this study underscores the impact of environmental, geographical, and processing factors on the quality and nutritional value of honey. Differences in the mineral concentrations across honey samples highlight the need for further research to understand these variations and their implications for honey quality. By examining the influence of factors such as soil composition, agricultural practices, and processing methods, researchers can gain insights into how these elements affect the nutritional profile of honey and contribute to its overall health benefits.

Conclusion

This study demonstrates significant variation in essential mineral concentrations between branded and unbranded honey, influenced by factors such as botanical sources, geographical origins, and environmental conditions. The analysis revealed notable differences in calcium, iron, zinc, magnesium, sodium, phosphorus, and potassium levels, with calcium content ranging from 23.05 to 31.66 mg/L, and the highest values observed in unbranded honey. These findings highlight the impact of diverse factors on honey's mineral composition and underscore the necessity for standardized quality control measures in honey production. The results emphasize the importance of considering the source and processing methods when evaluating honey's nutritional value. Further research is warranted to explore the implications of these variations for honey's health benefits and to establish more precise guidelines for honey quality assessment and labeling. Future studies should focus on a broader geographic range and include a more comprehensive analysis of additional trace elements to better understand their effects on honey's nutritional profile and quality.

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