

MINERAL CONTENT VARIATIONS IN LOCAL AND IMPORTED HONEY: A CASE STUDY IN KOSOVO

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Abstract

This study of mineral content variations in thirty local and imported honey samples from Kosovo focused on Zn, Ca, Fe, Cu, K, Mg, Mn, and Na. Mineral content was determined by MP-AES, and statistical analysis included ANOVA, Spearman's rank correlation, and Principal Component Analysis (PCA). Local honey contained higher levels of K, Fe, Mn, and Cu but lower levels of Na, Ca, Zn, and Mg compared to imported honey. Significant differences ($p < 0.05$) were observed in acacia honey for K and Mn, and in multifloral and forest honey for K, Mn, Na, Zn, and Cu. PCA clearly separated local and imported honeys, supporting the potential of mineral profiling for geographic origin differentiation. Positive correlations ($p < 0.05$ or $p < 0.01$) were detected among several mineral pairs in both local and imported honey samples, indicating synergistic accumulation influenced by botanical and environmental factors. Mineral concentrations remained below EU permissible levels for honey, confirming safety. These findings highlight the nutritional value of local honey and the influence of geographic and botanical origin on its mineral composition.

Keywords: imported honey, local honey, macro-minerals, micro-minerals, mineral composition

INTRODUCTION

Honey is a natural source of macro- and micro-minerals essential for human nutrition. Macro-minerals (K, Na, Ca, Mg, P, Cl) are required at >100 mg/day, while micro-minerals (Fe, Zn, Cu, Mn, Se, I) are required in smaller amounts (<100 mg/day) (Bogdanov et al., 2007; Belitz et al., 2009). Mineral composition is influenced by botanical origin, soil characteristics, environmental pollution, seasonal variation, and storage conditions (Hurrell, 2002; Ajibola et al., 2012). Kosovo's honey production is increasing, yet data on its mineral composition remain limited (Rysha et al., 2022). This study aims to compare the macro- and micro-mineral content of local and imported honey in Kosovo and evaluate the potential for origin differentiation.

MATERIALS AND METHODS

Sample collection

A total of thirty honey samples were selected for analysis, comprising fifteen locally produced and fifteen imported samples available on the Kosovo market. Sample selection was based on the following criteria: (i) clearly declared botanical origin (acacia, multifloral/meadow, or forest honey), (ii) confirmed geographic origin based on product labeling for imported honeys and direct procurement from registered beekeepers for local honeys, (iii) intact packaging and absence of visible crystallization defects, and (iv) commercial relevance and availability during the sampling period. Local honey samples were collected from five regions of Kosovo (Pejë, Prishtinë, Prizren, Mitrovicë, and Gjiilan), while imported samples originated from Germany, Turkey, Slovenia, Croatia, North Macedonia, and Albania. Each group included

representative proportions of acacia, multifloral, and forest honeys to ensure comparability between local and imported samples. Although the study was not designed to perform country-specific statistical comparisons, this distribution provided a representative overview of honey types commonly consumed in Kosovo.

Sample preparation and mineral analysis

Each 0.5 g honey sample was digested with 9 mL HNO₃ and 1 mL H₂O₂ using a microwave digestion system (Milestone ETHOS LEAN) with a four-step program (0-160°C, 10 min; 160°C, 5 min; 160-200°C, 1 min; 200°C, 10 min). Mineral content (Zn, Ca, Fe, Cu, K, Mg, Mn, Na) was determined by MP-AES (Agilent 4200) in triplicate.

Statistical analysis

Analysis of Variance ANOVA was applied to assess significant differences among honey types. Spearman's rank correlation coefficients were used to evaluate associations among minerals. In addition to univariate analysis, Principal Component Analysis (PCA) was applied as an exploratory multivariate technique to evaluate patterns in mineral composition and to assess the potential differentiation between local and imported honey samples. PCA was performed using standardized mineral concentration data, and components with eigenvalues greater than 1 were retained for interpretation. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Mineral composition

Potassium was the most abundant element in both Kosovo and imported honey samples, consistent with findings from other countries (Bilandžić et al., 2014; Conti et al., 2018). Significant variations were observed in K, Na, Ca, Mg, Zn, Fe, Mn, and Cu among honey samples (Tab. 1).

Local honey had higher K, Fe, Mn, and Cu levels, while imported honey showed higher Na, Ca, Zn, and Mg levels. Local acacia honey samples had significantly higher K and Mn levels ($p < 0.05$) than imported. In multifloral honey, local samples had higher K and Mn levels and lower Na levels ($p < 0.05$). Local forest honey samples had higher Cu levels ($p < 0.01$), whereas imported samples had higher Zn levels ($p < 0.05$).

Correlation analyses

Spearman correlation analysis showed significant positive associations among mineral elements in both local and imported honey samples. In local honey, significant correlations were observed between Zn and Na ($r_s = 0.596$, $p < 0.05$), Ca and K ($r_s = 0.586$, $p < 0.05$), Ca and Mg ($r_s = 0.607$, $p < 0.05$), K and Mg ($r_s = 0.539$, $p < 0.05$), and K and Mn ($r_s = 0.537$, $p < 0.05$). In imported honey, stronger positive correlations were identified, including Zn with Ca ($r_s = 0.704$, $p < 0.01$) and Mg ($r_s = 0.779$, $p < 0.01$), Ca with Mg ($r_s = 0.714$, $p < 0.01$), Fe with Mg ($r_s = 0.807$, $p < 0.01$) and Mn ($r_s = 0.677$, $p < 0.01$), as well as Mn with K ($r_s = 0.815$, $p < 0.01$). These

Table 1.
Macro-and micro-mineral content (mg/kg, mean $\pm$ SD) of local and imported honey

Honey type/Mineral	Local (Ks)	Imported (Is)	Significance (p)
Acacia - K	802.65 $\pm$ 289.50	198.77 $\pm$ 130.20	$p < 0.05$
Acacia - Mn	0.67 $\pm$ 0.11	0.24 $\pm$ 0.04	$p < 0.05$
Acacia - Ca	77.58 $\pm$ 4.20	92.67 $\pm$ 33.67	ns
Acacia - Zn	12.80 $\pm$ 7.85	8.37 $\pm$ 2.30	ns
Multifloral - K	743.90 $\pm$ 150.20	136.32 $\pm$ 65.65	$p < 0.01$
Multifloral- Mn	0.70 $\pm$ 0.34	0.22 $\pm$ 0.09	$p < 0.01$
Multifloral - Na	418.57 $\pm$ 130.80	645.42 $\pm$ 157.30	$p < 0.05$
Forest - Zn	8.10 $\pm$ 3.30	13.48 $\pm$ 4.44	$p < 0.05$
Forest - Cu	2.10 $\pm$ 0.44	0.59 $\pm$ 0.40	$p < 0.01$

ns - not significant

consistent positive relationships among K, Mg, Mn, Ca, and Zn across both honey groups suggest potential co-accumulation patterns driven by shared botanical origins and environmental conditions, in agreement with previous studies (Kacaniová et al., 2009; Matysek et al., 2018).

PCA analysis

PCA confirmed differentiation between local and imported honey based on mineral composition (Fig. 1). PC1 and PC2 together explained the majority of variance in mineral composition. Local honey was associated with higher loadings of K, Mn, Fe, and Cu, whereas imported honey was associated with Ca, Mg, Na, and Zn. These results support geographic origin differentiation using mineral profiles. The findings indicate that local honey in Kosovo is a valuable source of essential minerals, particularly K, Mn, Fe, and Cu. Botanical origin, soil composition, and environmental conditions are key determinants of mineral variability. The observed differences between local and imported honey have potential

relevance for nutritional evaluation and geographic traceability.

Variability and EU Regulatory Context

Variability in minerals (high SD in K, Zn, etc.) likely reflects botanical origin, seasonal foraging, soil composition, and storage conditions. Trace elements (Cu, Fe) were well below the EU maximum levels permitted under European Union food safety regulations, confirming the safety of all analyzed samples.

CONCLUSIONS

Local honeys from Kosovo are richer in K, Mn, Fe, and Cu, while imported honeys are higher in Ca, Mg, Na, and Zn. Positive correlations among minerals suggest synergistic accumulation. PCA supports differentiation between local and imported honeys, highlighting the potential of mineral profiling as a complementary tool for geographic origin assessment and confirming the nutritional quality of local honey.

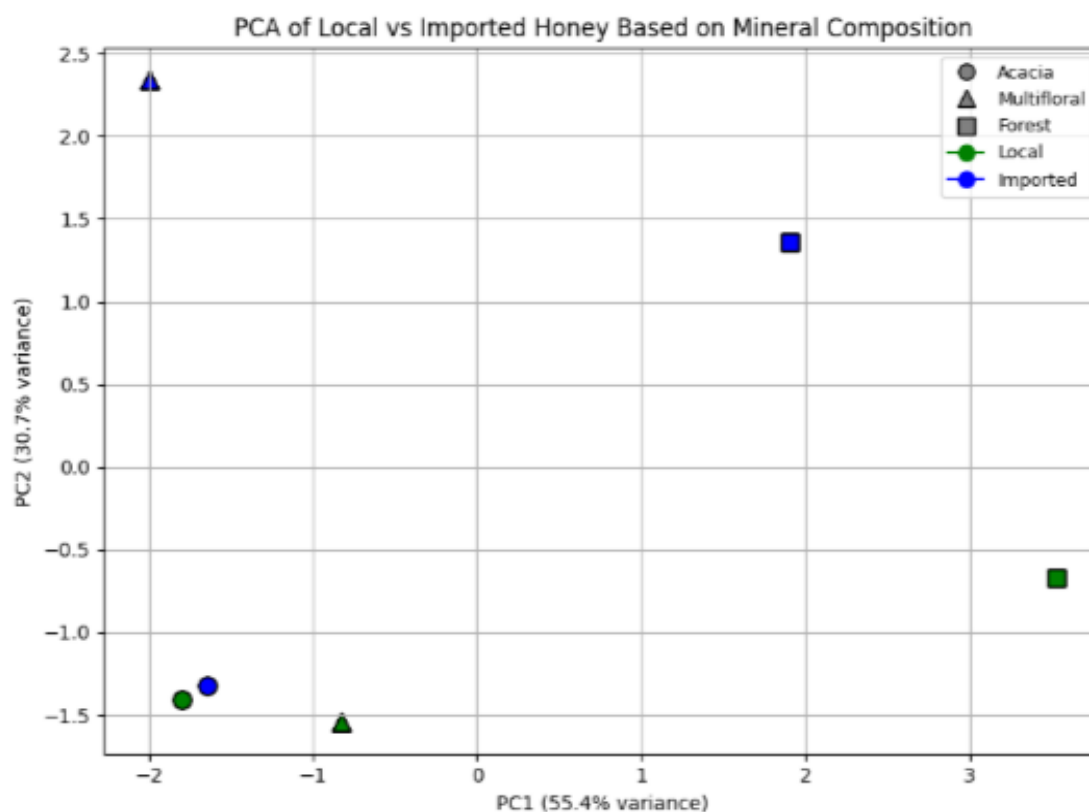


Fig. 1. Principal Component Analysis (PCA) of local (green) and imported (blue) honey samples based on mineral concentrations (Zn, Ca, Fe, Cu, K, Mg, Mn, Na). Marker shapes indicate honey type: circle=Acacia, triangle=Multifloral, square=Forest. PC1 and PC2 together explain the majority of variance and demonstrate clear differentiation between local and imported honey.

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