



Received: 14 March 2018
Accepted: 09 May 2018
First Published: 15 May 2018

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Reviewing editor:
Fatih Yildiz, Middle East Technical University, Turkey

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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Total phenolic, flavonoids and some selected metal content in honey and propolis samples from South Wolo zone, Amhara region, Ethiopia

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Abstract: Ethiopia is endowed with a variety of multifloral origin of honey and propolis. However, there is paucity of information on the chemical composition of honey and propolis for some of the regions. For this study, seven different types of honey and three propolis samples were collected from South Wolo zone districts of the Amhara region, Ethiopia. The total phenolic and flavonoids contents were estimated spectrophotometrically, while eight metal contents were analyzed using ICP-OES. Both honey and propolis samples were found to be rich in total phenolic content expressed as gallic acid equivalent (GAE) ranged from 45.42 to 73.51 mg GAE/100 g of honey and 204.4 to 262.5 mg GAE/100 g of propolis samples. The total flavonoids content expressed as catechin equivalent (CE) ranged from ND to 55.73 mg CE/100 g of honey and 187.7 to 214.9 mg CE/100 g of propolis. The mineral contents in the honey samples were in the range of 25–65 µg/100 g, 10–113 µg/100 g, 3.75–17.5 µg/100 g, 132.5–296.3 µg/100 g, 250–910 µg/100 g, and 807.5–6860 µg/100 g, respectively, for Cr, Co, Cd, Mg, Ca, and Fe. However, Ni and Cu were not detected in the samples. Cd was found below the maximum permissible limit. Thus, the honey samples collected from South Wolo zone of the Amhara region, Ethiopia are of good quality in terms of heavy metal



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ABOUT THE AUTHOR

Dr. Minaleshewa Atlabachew's research group is consisted of some staff members of the Bahir Dar University and postgraduate (MSc and PhD) students. Dr. Minaleshewa Atlabachew is a full time associate professor of analytical chemistry in Bahir Dar University. He graduated with B.Ed in Chemistry from Bahir Dar University, Ethiopia in 2004, MSc and PhD in Analytical Chemistry from Addis Ababa University in 2007 and 2013, respectively. From 2014 to 2016, he was a postdoctoral fellow at the Tshwane University of Technology, South Africa. Minaleshewa Atlabachew's research group spans the development of modern sample preparation techniques for bioactive molecules investigation and extensive use of the advanced analytical techniques together with multivariate data analysis for quality control of indigenous natural products. So far, he authored/coauthored more than 24 peer-reviewed original research articles.

PUBLIC INTEREST STATEMENT

Since honey and propolis are rich in phytochemical, their composition and bioactivity depend on the floral source, the method used to collect the nectar, seasonal and environmental factors, and geographic origin. Furthermore, honey may be useful as an environmental indicator of heavy metal pollution as honeybees may be continuously exposed to contaminants.

Even though Ethiopia has diversified agroecological conditions and a variety of multifloral origin of honeys and propolis are available in the different areas of the country, their composition and quality have not been well investigated. Secondly, white honey is traditionally more valuable than colored honeys. Hence, this article describes the dependence of phenolic compounds on the color of the honey and propolis, as well as the mineral composition of some of the well-known honey samples. Thus, consumers' pharmacologists and nutritionist can now select the honey and propolis types of their interest for their consumption or concentration-based studies.

contamination and contained relatively good composition of phenolic compounds as compared to some honey samples reported from overseas.

Subjects: Cancer; Environmental & Ecological Toxicology; Food Additives & Ingredients; Food Chemistry; Complementary and Integrative Medicine; Nutrition and Dietetics

Keywords: phenolic compounds; honey; propolis; flavonoids; metal; Ethiopia

1. Introduction

Honey and propolis are natural substances of honeybee products which have potential role in contributing to human health (Chua, Rahaman, Adnan, & Eddie Tan, 2013). Honey is produced by honeybees (*Apis mellifera*) from nectar, while propolis is one of the honeybee products with sticky and resinous nature. It is collected by honeybees from buds and barks of different trees and enriched in the beehive by addition of salivated secretions and wax (Bankova et al, 2000; Sime, Atlabachew, Abshiro, & Zewde, 2015).

Honey and propolis contained several classes of phenolic acids, flavonoids, vitamins, enzymes, carbohydrate, pigments, aroma, and minerals (Chua et al., 2013). The composition and the quantity of these phytochemicals are highly dependent on the influence of plants, climatic and environmental conditions, production methods, processing and storage conditions, as well as the nectar source of the honey (Kiliç Altun, Dinç, Paksoy, Temamoğulları, & Savrunlu, 2017; Sime et al., 2015).

Although honey is best known by its sugar content and other phytochemicals, the presence of essential and toxic metals has also been reported in several articles (Kiliç Altun et al., 2017; Mondragón-Cortez, Ulloa, Rosas-Ulloa, Rodríguez-Rodríguez, & Resendiz Vázquez, 2013). As indicated elsewhere, the sources of these minerals are the soil whereby the plants uptake it and translocate it in the nectar, and afterward it is inculcated into the honey (Liberato et al., 2013; Rodríguez García et al., 2006; Stankovska, Stafilov, & Šajin, 2008). Thus, the soil chemistry and geological feature together with type of the flowing plant have influence on the overall mineral composition of honey (Pohl, 2009).

Minerals such as Co, Zn, Fe, Ni, Cu, and Mn are required for human's metabolism at a certain concentration level. However, above the permissible limits, they are considered as toxic and hazardous to human. The levels of Pb and Cd are unacceptable owing to their carcinogenic and cytotoxic influences (Kiliç Altun et al., 2017).

In addition to natural sources, polluted environments have an impact on the quality of honey in terms of its mineral content. Heavy metals might be accumulated in the nectar through emissions of gases and particles or through translocation from the root (Liberato et al., 2013). Thus, the level of heavy metals in honey is an indicative of the environmental pollution of the region and geographical origin of the honey samples, as well as the quality of the honey (Lachman et al., 2007; Liberato et al., 2013).

Even though Sime et al. (2015) have investigated the phenolic composition and antioxidant activity of honey and propolis samples collected from eastern, western, and sothern parts of Ethiopia, the data available about the organic and inorganic contents of Ethiopian honey as well as propolis are insufficient. Particularly, the phenolic constituents were not studied in honey samples from the northern parts of the country. Furthermore, there is paucity of information on the mineral content of Ethiopian honey, unlike honey samples from overseas countries.

It has to be noted that the Ethiopian natural honey and propolis are thought to be of different varieties due to the unique and highly diverse flora of the country because of its rich variety of environmental features ranging from semidesert to mountain forests and its wide range of ecological, edaphic, and climatic conditions. There are over 7,000 flowering plants species recorded, of which 12% are probably endemic to Ethiopia and most of them are bee plants

(Fikru, 2015; Simie et al., 2015). Ethiopia has the largest bee population in Africa with over 10-million bee colonies, out of which about 5–7.5 million are estimated to be hived while the remaining exist in the wild (Legesse, 2014; MoARD, 2007). The annual honey production of Ethiopia is estimated to be 45,300 metric tons which makes the country to rank first honey producing country in Africa and ninth in the world (FAO, 2010; Fikru, 2015). Ethiopia exports honey to France, Japan, Korea Republic, Norway, Sweden, UK, Somalia, and Sudan (<http://www.ethiopianimporter.com/ethiopia-export-data/honey.html>).

The test, aroma, and texture of honey from the northern part of the country are recognizably different since the vegetation is different from the rest of the regions of the country. Therefore, this study was designed to determine the mineral composition and to estimate the phenolic content and antioxidant activity of honey and propolis samples collected from Amhara region of Ethiopia, more specifically from south Wollo zone districts.

2. Experimental

2.1. Materials and equipment

Double beam UV ($\lambda=35$) spectrometry inductively coupled plasma optic emission spectrophotometer (ICP-OES, optima 8000 I-Perkin Elmer).

2.2. Chemical and reagents

Anhydrous sodium carbonate, orthophosphoric acid (85%) and sodium molybdate dehydrate (98%), anhydrous AlCl_3 , Na_2NO_2 , anhydrous sodium tungstate ($\text{Na}_2\text{WO}_4 \cdot 2\text{H}_2\text{O}$), phosphomolybdic acid, ethanol and methanol, gallic acid, catechin, anhydrous Na_2CO_3 , NaOH , HCl (37%), Br_2 , Li_2SO_4 , 69.5% HNO_3 , H_2O_2 (30%), and metal standards were used.

3. Description of the study area

Samples were collected from the northern part of Ethiopia called Amhara regional state and more specifically from South Wollo zone (Figure 1). The state is one of the major honey producing areas of the country. Honeys from this area have distinct flavor, color, and texture.

4. Collection of natural honey and propolis samples

Seven natural honeys and three propolis samples (Figure 2) from traditional hives were randomly collected from different geographical areas of the South Wollo zone, namely, Ambamaryam district, Mekena district, Adjibar district, Tenta district, Wortej district, Kolo district, and Chihna district. From one particular area, three to five hives were considered. From each hive, about 300 g

Figure 1. Map showing the sampling area.

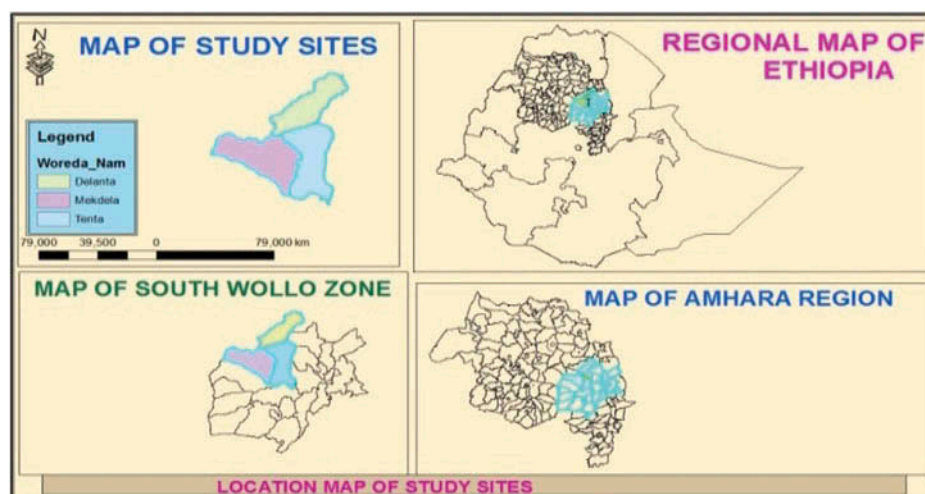


Figure 2. The three propolis and seven honey samples collected from study areas.



of honey was collected and samples from similar area were mixed together to get a bulk sample. Table 1 shows details of the samples.

5. Sample preparation

The honey and propolis samples were processed for phenolic compounds analysis following the method reported by Sime et al. (2015). For honey samples, about 2.5 g of each sample was mixed with 50 mL of distilled water. The filtrate was taken for analysis, whereas for the propolis samples, 5 g of each sample was mixed with 50 mL of 70% methanol in water and kept for 1 week by shaking intermittently. The filtrate was directly used for analysis. Total phenolics and total flavonoids contents were determined spectrophotometrically (Sime et al., 2015).

6. Determination of total phenolic compounds in honey and propolis samples

The total phenolic compounds of the seven honey and propolis samples were determined according to the Folin–Ciocalteu method (Sime et al., 2015). One milliliter of either honey solution (0.05 g/mL) or propolis (0.1 g/mL) was mixed with 2.5 mL of 7.5% sodium carbonate (Na_2CO_3) solution and 2.5 mL of 4% sodium carbonate (Na_2CO_3) solution. To the mixture, 0.5 mL of Folin–Ciocalteu reagent which was prepared following the method reported by Bizuayehu et al. (2016) was added and the absorbance of the resulting solution was measured at 740 nm using double beam UV/Vis spectrophotometer (lambda-35). All the measurements were done in triplicate and gallic acid was used as a reference standard. The results were expressed as mg gallic acid equivalents (GAEs) per 100 g of samples.

7. Determination of total flavonoid compounds in honey and propolis samples

The total flavonoid contents (TFCs) of the honey samples were determined using aluminum chloride method and D-catechin as standard (Sime et al., 2015). Results were expressed as mg catechin equivalent/100 g honey or propolis samples.

Table 1. Description of sample type and sampling date

Sample code	Site of collection	Type of honey and color consistency	Harvest date (2016)	Production type
NH-1	Tenta district	Whitish yellow multifloral honey	October	Traditional
NH-2	Kolo district	Red multifloral	November	Traditional
NH-3	Kolo district	Medium yellow multifloral honey	December	Traditional
NH-4	Chihna district	Red multifloral	December	Traditional
NH-5	Wortej district	White multifloral	October	Traditional
NH-6	Mekena district	Whit multifloral honey	October	Traditional
NH-7	Ambamaryam district	Red multifloral honey	September	Traditional
Pro-1	Mekena district	Black multifloral propolis	March	Traditional
Pro-2	Mekena district	Medium black multifloral propolis	March	Traditional
Pro-3	Adjibar district	Light black multifloral propolis	March	Traditional

8. Determination of metals content in honey

Honey samples were digested following the method reported by Taddia, Musiani, & Schiavi (2004). About 4.0 g of honey sample was digested on a kjeldahl digestion apparatus using a mixture of HNO₃ and HClO₄. The digested samples were diluted to 50 mL and filtered. The concentration of the elements (Cr, Co, Ni, Cu, Cd, Fe, Ca, and Mg) in the digested solution of honey was determined using ICP-OES. Results were expressed as µg/100 g sample and the data are presented in Table 4.

In order to evaluate the efficiency of the digestion procedure, 4.0 g of one of the honey sample (NH_1) was taken and spiked with 2.6 µg, 0.8 µg, 0.4 µg, 8.5 µg, 5.0 µg, 5.0 µg, 25.0 µg, and 5.0 µg of Cr, Co, Cd, Ni, Cu, Mg, Ca, and Fe, respectively. The spiked mixture was digested similar to the unspiked sample. Results of the recovery experiment are indicated in Table 3. Following the same procedure, three blank samples were digested to calculate the detection limit of the method.

9. Statistical analysis

All the determinations were carried out in triplicate, and the data were expressed as mean ± standard deviation (SD). Significant differences of the data among the parameters were determined by analysis of variance (ANOVA) test with the help of SPSS version 20 software and mean values were compared by Tukey's HSD (homogeneous subset difference) test. Difference at ($p \leq 0.05$) was considered significant.

10. Result and discussion

10.1 Total phenolic content (TPC) in honey and propolis

The TPC of the honey and propolis samples were estimated from the regression equation ($y = 0.015 \times -0.053$; $R^2 = 0.9987$) of gallic acid which was derived from concentration ranging from 2.89 to 61.53 µg/mL. All data were acquired in triplicate and results are expressed in mean ± standard deviation ($n = 3$, mean ± SD). Results are presented in Table 2.

In the studied honey samples, the TPC was ranged from 45.4 ± 2.08 mg GAE/100 g (sample from Mekena district, NH-5) to 73.5 ± 5.43 mg GAE/100g (sample from Ambamaryam district, NH-7). In general, dark red colored honey samples (NH-7, NH-4, and NH-2) have shown the highest total phenolics content followed by light yellowish honey (NH-3 and NH-1) and whitish honey (NH-5 and NH-6). The same trend was obtained in other study (Sime et al., 2015). The data from this study were found to be about 5–10 times lower than the data obtained from other regions of Ethiopia (Sime et al., 2015). This is attributable to the differences in the floral origin of the northern part of

Table 2. The total phenol content (TPC) and total flavonoids content (TFC) of seven honey and three propolis samples, expressed as (mean ± SD, $n = 3$)

Types of sample	TPC (mg GAE/100 g) samples	TFC (mg CE/100 g) samples
NH_1	51.7 ± 4.13^a	11.1 ± 2.3^a
NH_2	75.0 ± 3.08^b	10.9 ± 0.93^a
NH_3	58.4 ± 2.92^c	1.50 ± 0.12^b
NH_4	68.4 ± 5.08^d	41.7 ± 0.61^c
NH_5	45.4 ± 2.08^e	2.7 ± 0.10^d
NH_6	52.8 ± 1.08^a	ND
NH_7	73.5 ± 5.43^b	55.7 ± 4.23^e
PRO_1	262.5 ± 10.20^f	214.9 ± 13.86^f
PRO_2	204.4 ± 8.04^g	187.7 ± 11.61^g
PRO_3	236.2 ± 9.23^h	192.40 ± 0.87^h

Values in the same column that are followed by a different letters (a–f) are significantly different at $p \leq 0.05$ by Tukey (homogeneous subset difference) test. ND = no detected.

Table 3. Recovery test of honey sample

Element	Concentration before spiked (mg/L)	Spiked concentration (mg/L)	% recovery (mean ± SD)	Limit of detection (LOD)	Limit of quantification (LOQ)
Cr	0.052	0.052	94.9 ± 4.45	0.0004	0.0015
Co	0.016	0.016	90.9 ± 3.47	0.0046	0.016
Cd	0.008	0.008	91.6 ± 11.4	0.0037	0.0123
Cu	0	0.10	103 ± 8.98	0.0844	0.2816
Ni	0	0.10	91.7 ± 3.07	0.0067	0.0223
Mg	0.17	0.17	88.2 ± 5.89	0.00462	0.0154
Ca	0.496	0.50	89.5 ± 9.83	0.0216	0.072
Fe	5.488	0.10	91.4 ± 10.6	0.2633	0.8788

the country as compared to the eastern, southern, and western parts of the country. However, it was found to be comparable with Malaysian Tualang honey, Gelam honey, and New Zealand Manuka honey (18.5–87.6 mg GAE/100g, 44.9–48.4 mg GAE/100g, and 43.5 mg GAE/100g, respectively) (Khalil, Mahaneem, Jamalullail, Alam, & Sulaiman, 2011).

The TPC of the propolis samples in this study ranged from 204.44 ± 8.04 mg GAE/100 g propolis sample (sample from Adjibar district) to 262.51 ± 10.20 mg GAE/100g propolis (sample from Mekena district). Propolis sample (Pro-1) has higher TPC, which was very black in color followed by the medium-blackened (pro-3) and light black (pro-2). This trend is in agreement with the result reported by Sime et al. (2015), but the data found in this study are 1.5–4 times lower than the reported data from the other regions of the country.

10.2. Total flavonoid content (TFC) in honey and propolis samples

The content of total flavonoid in the honey and propolis samples were derived from standard curve of catechin ranged from 5.0 to 320 µg in 5 mL ($y = 0.005x + 0.068$; $R^2 = 0.9959$). The TFCs of the seven honey samples and three propolis samples expressed as mg catechin/100g of samples are given in Table 2. The TFC of the tested honey samples ranged from 1.5 ± 0.12 mg CE/100g (sample from Kolo district) to 55.7 ± 4.23 mg CE/100g (sample from Ambamaryam district). The red honey samples (NH-7 and NH-4) collected from Ambamaryam and Chihna district were found to contain significantly higher flavonoids content as compared to white honey (NH-6) and slightly yellowish honey (NH-3). Among the studied samples, flavonoids were not detected in white honey (NH-6). This confirms the dependence of flavonoids on the color of the honey samples. Comparing with the earlier study on Ethiopian honey, the honey sample (NH-7) was found to contain slightly higher concentration than one of the honey sample reported by Sime et al. (2015), while the TFCs in the other honey samples were lower than the data reported by Sime et al. (2015). One potential source of variation in TFC is because these honey samples were obtained from different beekeepers in various geographical regions and/or at different harvesting area. Even within honeys from a particular floral source, the composition can vary depending on climate and environmental stress factors, such as humidity, temperature, and soil composition (Khalil et al., 2011; Perna, Simonetti, Intaglietta, Sofo, & Gambacorta, 2012; Wieczorek, Pietrzak, Pomianowski, & Wieczorek, 2014).

Looking at the TFC in propolis samples (Table 2), the black propolis (pro-1: 262.5 ± 10.20 mg CE/100g sample) contained considerable amounts of flavonoids than the medium (pro-3: 192.40 ± 0.87 mg CE/100 g sample) and light black propolis (pro-2: 187.7 ± 11.61 mg CE/100g samples). The observed variation in the flavonoid concentration of the investigated propolis is mainly accounted to the difference in the preferred regional plants (flora) collected by bees.

Table 4. Total mean concentration ($\mu\text{g}/100\text{ g}$ honey) of each metal in seven different honey samples

Types of honey	Elements with total mean \pm SD of seven honey samples in $\mu\text{g}/100\text{ g}$ honey										Total
	Cr	Co	Cd	Ni	Cu	Mg	Ca	Fe			
NH_1	65.0 \pm 1.3 ^A	20.0 \pm 1.7 ^A	10.0 \pm 0.63 ^A	ND	ND	212.5 \pm 10.75 ^A	620 \pm 29.1 ^A	6860 \pm 192 ^A			7788
NH_2	57.5 \pm 2.5 ^B	12.5 \pm 2.13 ^B	10.9 \pm 0.75 ^A	ND	ND	162.5 \pm 3.50 ^B	250 \pm 27.5 ^B	5510 \pm 226 ^B			6003
NH_3	53.8 \pm 1.63 ^C	114.0 \pm 7.5 ^C	17.5 \pm 0.5 ^B	ND	ND	172.5 \pm 1.25 ^C	425 \pm 23.7 ^C	5450 \pm 142 ^C			6233
NH_4	60 \pm 1.75 ^B	21.3 \pm 1.63 ^{AD}	12.5 \pm 4.3 ^C	ND	ND	147.5 \pm 2.75 ^D	870 \pm 67.0 ^D	3738 \pm 113 ^D			4849
NH_5	33.8 \pm 0.63 ^D	23.8 \pm 3.87 ^D	7.5 \pm 1.13 ^D	ND	ND	132.5 \pm 3.25 ^E	790 \pm 32.9 ^E	3172 \pm 98.8 ^E			4160
NH_6	25.0 \pm 1.37 ^E	31.3 \pm 3.75 ^E	12.5 \pm 0.25 ^C	ND	ND	127.5 \pm 3.25 ^E	624 \pm 22.1 ^A	807 \pm 133 ^F			1627
NH_7	63.8 \pm 1.25 ^A	10.0 \pm 1.63 ^F	3.75 \pm 1.50 ^D	ND	ND	296 \pm 2.50 ^F	910 \pm 80.0 ^F	4234 \pm 40.8 ^G			5518

Values in the same column that are followed by a different letters (A–F) are significantly different at $p \leq 0.05$ by Tukey (homogeneous subset difference) test. The mean difference is significant at 0.05 levels. ND = no detected.

11. Elemental analysis

11.1. Method evaluation

The average recovery of each of the metals from the spiked sample is tabulated and shown in Table 3. The recoveries of the metals in the spiked honey sample were ranged between 88% and 103%. This indicates that the performance of the digestion method was within the acceptable range (80–120%).

11.2. Level of metals in honey samples

Table 4 shows the concentration of eight elements in seven honey samples collected from the northern part of Ethiopia, specifically from North Wolo zone districts. It was observed that the concentration of the eight elements varied widely within the different honey samples. Last column of Table 4 shows the total concentration of the element calculated by summing up the mean concentration of each of the eight elements investigated in a particular honey sample.

It was found that the yellowish honey sample (NH-1) from Tenta district had the highest mineral content (7,788 $\mu\text{g}/100\text{ g}$) followed by medium yellowish honey sample (NH-3) from Kolo district (6,233 $\mu\text{g}/100\text{ g}$) and reddish honey (NH-2) from Kolo district (6,003 $\mu\text{g}/100\text{ g}$). It has to be noted that the highest concentration of total element in the samples (NH-1, NH-2, and NH-3) was mainly due to the presence of Fe in high concentration as compared to the other elements.

Iron (Fe) is one of the critical elements for humans due to its role in the production of red blood cells and its association with hemoglobin and the transfer of oxygen from lungs to the tissue cells. Fe was the most abundant among the tested metals in all the samples ranged from 807 to 6880 $\mu\text{g}/100\text{ g}$. The high concentration of Fe in the studied samples might be due to the high Fe concentration in the pollen and environment as a whole. The Fe concentration obtained from this study is higher than Turkish honey (0.1–700 $\mu\text{g}/100\text{ g}$), Brazilian honey (178–3,828 $\mu\text{g}/100\text{ g}$), Rumanian honey (2.2 $\mu\text{g}/100\text{ g}$), Egyptian honey (277 $\mu\text{g}/100\text{ g}$), Greece honey (239 $\mu\text{g}/100\text{ g}$) (Kılıç Altun et al., 2017; Mendes et al., 2008; Santos, Santos, Santos, Santos, & Lacerda, 2008), while a relatively higher concentration of Fe was reported in honey samples from Saudi Arabia (6,960–9,813 $\mu\text{g}/100\text{ g}$) (Alqarni, Owayss, Mahmoud, & Hannan, 2014) and from some other countries (Table 5). This variation can be ascribed to variation in the floral origin, as well as soil composition of the regions. On the other hand, some of the honey samples from Malaysia contained an Fe concentration closer to our finding (Chua et al., 2012).

Although most of the reported articles indicated that the relative concentration of Fe was lower than those of Ca and Mg (Pohl, 2009; Rashed et al, 2004; others). However, in accordance with our data, a relatively higher concentration of Fe followed by Ca and Mg was reported in most of the Malaysian honey except Manuka and few other honey types (Moniruzzaman, Chowdhury, Rahman, Sulaiman, & Gan, 2014).

Calcium (Ca) is the major abundant mineral in the body. Ca is mainly found in the bones and teeth (Dhahir & Hemed, 2015). The Ca level in the studied honey samples varies over a range of 250–910 $\mu\text{g}/100\text{ g}$. The Ca concentration obtained from this study is higher than those reported from Malaysia, Turkey, Egypt, and Kenya (Table 5), while a lower concentration of Ca was obtained in this study as compared to honey samples from Brazil, Czech, France, India, Ireland, Italy, Macedonia, Spain, and Turkey (Table 5).

In this study, the concentration of Mg was ranging from 127 to 296 $\mu\text{g}/100\text{ g}$. This concentration range is lower as compared to some known honey samples (Table 5). Karabagias et al. (2017) reported higher mean values of magnesium ranging from 810 to 1320 $\mu\text{g}/100\text{ g}$ in a study carried out on 37 honey samples collected from Egypt, Spain, Greece, and Morocco. The same concentration range (600–3300 $\mu\text{g}/100\text{ g}$) was reported by Santos et al. (2008) on 52 honey samples produced in three different regional climates in the southwest Bahia, Brazil (semiarid, Atlantic

Table 5. Comparison of the concentration ($\mu\text{g}/100\text{ g}$) of metals in the studied samples with literature data

Origin	Cr	Co	Cd	Ni	Cu	Mg	Ca	Fe	Ref.
Mexico	-	-	-	-	-	13.1-24.6	38.6-127.3	0.82-4.72	Mondragón-Cortez et al., 2013
Brazil	-	-	-	-	ND	ND-373	7.0-237	ND-15.0	Mendes et al., 2008; Santos et al., 2008
Chile	0.03-1.98	0.03-0.6	0.01-0.05	0.01-1.48	0.06-4.32	-	-	0.10-7.66	Fredes et al., 2006
Czech	-	-	-	0.06-1.53	0.12-0.89	18.5-89.1	11.3-142	-	Lachman et al., 2007
Egypt	-	1.75-3.20	0.010-0.5	1.25-4.10	1.00-1.75	103-1322	-	58-3691	Rashed & Soltan, 2004
France	-	-	0.08-0.25	0.09-0.34	0.03-2.30	1.43-110	2.98-108	0.1-87.0	Devillers et al., 2002
Malaysia	3.08-3.68	ND-3.97	ND	ND-0.084	0.046-0.19	3.6-87.1	ND	11.0-31.1	Chua et al., 2012
Hungary	0.0018-0.109	-	0.0008-0.0033	-	0.04-0.44	-	-	-	Ajtóny, Bencs, Haraszi, Sziget, & Szoboszlai, 2007
India	-	0.05-0.25	0.3-0.5	0.37-0.4	1.06-2.91	-	32.6-84.6	3.60-28.4	Nanda, Sarkar, Sharma, & Bawa, 2003; Buldini, Cavalli, Mevoli, & Sharma, 2001
Ireland	-	ND	-	-	1.00-2.30	18.9-53.3	74.9-175	1.70-36.3	Downey, Hussey, Kelly, Walshe, & Martin, 2005
Italy	ND-0.089	0.002-0.057	ND	ND-2.76	0.14-5.90	3.90-159	9.10-409	0.30-35.1	Caroli, Forte, Iamicieli, & Galoppi, 1999; Pisani, Protano, & Riccobono, 2008
Macedonia	-	-	0.001-0.27	-	0.02-5.90	4.40-182	4.10-170	0.03-7.00	Stankovska et al., 2008
Poland	-	-	-	-	ND-1.82	1.10-19.8	3.30-159	ND-16.1	Przybyłowski & Wilczyńska, 2001; Madejczyk & Barakiewicz, 2008
Spain	0.006-0.041	-	0.0008-0.006	0.012-0.17	0.04-7.80	18.0-308	41-385	ND-21.0	Rodríguez García et al., 2006
Turkey	0.002-0.54	-	<0.001	0.00-0.42	ND-3.50	0.001-111	0.001-900	0.04-19.7	Üren, Şerifoglu, & Sarıkahya; Kiliç Altun et al., 2017
Ethiopia	0.25-0.65	0.1-1.14	0.038-0.18	ND	ND	1.28-2.96	2.50-9.10	8.07-68.6	This study

and Transitional Forest Zones). In a study carried out by Chua et al. (2012), much higher magnesium content was reported (mean values ranging from 5200 to 8950 µg/100 g).

Besides the major minerals (Ca, Mg, and Fe), minor elements such as Co, Cr, and Cd were also detected in the studied honey samples, while Ni and Cu were below the detection limit of the instrument. The three elements are present in less than 1 µg/g in all the studied samples. The concentration range of Cr, Co, and Cd was 25–65 µg/100 g, 10–114 µg/100 g, and 4.0–17.0 µg/100 g, respectively. Comparing with literature values, a significantly higher concentration of Cr, Co, Cd, Ni, and Cu was reported in most of honey samples collected from Africa, Asia, and Europe (Table 5).

The low concentrations of Cr, Ni, Cd, and Cu are attributed to the uncontaminated environment of the sampling area. The districts where these samples were taken are less industrialized area and farming is the only source of the livelihood.

12. Conclusion

In this report, we have presented the TPC, total flavonoids, and some selected macro- and microelements in seven honey and three propolis samples collected from the northern part of Ethiopia, South Wolo zone districts. The composition of the honey and the propolis samples vary with the color of the honey and geographical origin. This study confirmed that colored honey and propolis samples were rich in phenolic compounds than the white or light colored samples, which signifies that the former samples are medicinally more important in terms of phenolic content. The mineral data suggested that honey samples of South Wolo zone districts of the Amhara region of Ethiopia were of good quality because the concentration of some of the toxic heavy metals were below the maximum permissible limit.

Acknowledgments

Authors would like to acknowledge Bahir Dar University for covering the research cost

Funding

The authors received no direct funding for this research.

Competing interest

The authors declare no competing interest.

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Citation information

Cite this article as: Total phenolic, flavonoids and some selected metal content in honey and propolis samples from South Wolo zone, Amhara region, Ethiopia, Tesfaye Liben, Minaleshewa Atlabachew & Atakilt Abebe, *Cogent Food & Agriculture* (2018), 4: 1475925.

References

Ajtay, Z., Bencs, L., Haraszi, R., Szigeti, J., & Szoboszlai, N. (2007). Study on the simultaneous determination of some essential and toxic trace elements in honey by multi-element graphite furnace atomic absorption

spectrometry. *Talanta*, 71(2), 683–690. doi:10.1016/j.talanta.2006.05.023

Alqarni, A. S., Owayss, A. A., Mahmoud, A. A., & Hannan, M. A. (2014). Mineral content and physical properties of local and imported honeys in Saudi Arabia. *Journal of Saudi Chemical Society*, 18(5), 618–625. doi:10.1016/j.jscs.2012.11.009

Bankova, V., de Castro, S.L., & Marcucci, M.C. (2000). Propolis: recent advances in chemistry and plant origin. *Apidologie*, 31(1), 3–15. doi:10.1051/apido:2000102

Bizuayehu, D., Atlabachew, M., & Ali, M. T. (2016). Determination of some selected secondary metabolites and their in vitro antioxidant activity in commercially available Ethiopian tea (*Camellia sinensis*). *SpringerPlus*, 5(1), 1. doi:10.1186/s40064-016-2056-1

Buldini, P. L., Cavalli, S., Mevoli, A., & Sharma, J. L. (2001). Ion chromatographic and voltammetric determination of heavy and transition metals in honey. *Food Chemistry*, 73(4), 487–495. doi:10.1016/S0308-8146(01)00132-7

Caroli, S., Forte, G., Iamiceli, A. L., & Galoppi, B. (1999). Determination of essential and potentially toxic trace elements in honey by inductively coupled plasma-based techniques. *Talanta*, 50(2), 327–336. doi:10.1016/S0039-9140(99)00025-9

Chua, L. S., Abdul-Rahaman, N. L., Sarmidi, M. R. & Aziz, R. (2012). Multi-elemental composition and physical properties of honey samples from Malaysia. *Food Chemistry*, 135(3), 880–887.

Chua, L. S., Rahaman, N. L. A., Adnan, N. A., & Eddie Tan, T. T. (2013). Antioxidant activity of three honey samples in relation with their biochemical components. *Journal of Analytical Methods in Chemistry*, 2013, 1–8. doi:10.1155/2013/313798

Devillers, J., Dore, J. C., Marengo, M., Poirier-Duchene, F., Galand, N., & Viel, C. (2002). Chemometrical analysis of 18 metallic and nonmetallic elements found in

- honey sold in France. *Journal of Agricultural and Food Chemistry*, 50(21), 5998–6007. doi:10.1021/jf020497r
- Dhahir, S.A., & Hemed, A.H. (2015). Determination of heavy metals and trace element levels in honey samples from different regions of Iraq and compared with other kind. *American Journal Of Applied Chemistry*, 3(3), 83–92.
- Downey, G., Hussey, K., Kelly, J. D., Walshe, T. F., & Martin, P. G. (2005). Preliminary contribution to the characterisation of artisanal honey produced on the island of Ireland by palynological and physico-chemical data. *Food Chemistry*, 91(2), 347–354. doi:10.1016/j.foodchem.2004.06.020
- FAO. (2010). *FAOSTAT database on agriculture and nutrition*. Rome, Italy: Food and Agricultural Organization of the United Nations. Retrieved from <http://faostat.fao.org/site/569>
- Fikru, S. (2015). Review of honey bee and honey production in Ethiopia. *Journal of Animal Science Advances*, 5(10), 1413–1421. doi:10.5455/jasa.20151019083635
- Fredes, C., & Montenegro, G. (2006). Heavy metal and other trace elements contents in honey bee in Chile. *Ciencia E Investigación Agraria*, 33(1), 50–58. doi:10.7764/rcia.v33i1.328
- Karabagias, I. K., Louppis, A. P., Karabournioti, S., Kontakos, S., Papastephanou, C., & Kontominas, M. G. (2017). Characterization and geographical discrimination of commercial Citrus spp. honeys produced in different Mediterranean countries based on minerals, volatile compounds and physicochemical parameters, using chemometrics. *Food Chemistry*, 217, 445–455. doi:10.1016/j.foodchem.2016.08.124
- Khalil, M. I., Mahaneem, M., Jamalullail, S. M. S., Alam, N., & Sulaiman, S. A. (2011). Evaluation of radical scavenging activity and colour intensity of nine Malaysian honeys of different origin. *Journal of ApiProduct and ApiMedical Science*, 3(1), 04–11. doi:10.3896/IBRA.4.03.1.02
- Kılıç Altun, S., Dinç, H., Paksoy, N., Temamoğulları, F. K., & Savrunlu, M. (2017). Analyses of mineral content and heavy metal of honey samples from south and east region of Turkey by using ICP-MS. *International Journal of Analytical Chemistry*, 2017.
- Lachman, J., Kolihovala, D., Miholova, D., Košata, J., Titěra, D., & Kult, K. (2007). Analysis of minority honey components: Possible use for the evaluation of honey quality. *Food Chemistry*, 101(3), 973–979. doi:10.1016/j.foodchem.2006.02.049
- Legesse, G. Y. (2014). Review of progress in Ethiopian honey production and marketing. *Livestock Research for Rural Development*. Volume 26, Article #14. Retrieved March 13, 2018, from <http://www.lrrd.org/lrrd26/1/lege26014.htm>
- Liberato, M. D. C. T. C., Morais, S. M. D., Magalhães, C. E. D. C., Magalhães, I. L., Cavalcanti, D. B., & Silva, M. M. D. O. (2013). Physicochemical properties and mineral and protein content of honey samples from Ceará state, northeastern Brazil. *Food Science and Technology (Campinas)*, 33(1), 38–46. doi:10.1590/S0101-20612013005000028
- Madejczyk, M., & Baralkiewicz, D. (2008). Characterization of Polish rape and honeydew honey according to their mineral contents using ICP-MS and F-AAS/AES. *Analytica Chimica Acta*, 617(1–2), 11–17. doi:10.1016/j.aca.2008.01.038
- Mendes, T. M. F. F., Baccan, S. N., & Cadore, S. (2008). Sample treatment procedures for the determination of mineral constituents in honey by ICP-OES. *Journal of the Brazilian Chemical Society*, 17(1), 168–176. doi:10.1590/S0103-50532006000100024
- MoARD (2007). *Livestock development master plan study phase I report—Data collection and analysis*, Volume Napiculture, Minist. Agri. Rural Dev. (MoARD). Ethiopia: Addis Ababa.
- Mondragón-Cortez, P., Ulloa, J. A., Rosas-Ulloa, P., Rodríguez-Rodríguez, R., & Resendiz Vázquez, J. A. (2013). Physicochemical characterization of honey from the west region of México. *CyTA-Journal of Food*, 11(1), 7–13. doi:10.1080/19476337.2012.673175
- Moniruzzaman, M., Chowdhury, M. A. Z., Rahman, M. A., Sulaiman, S. A., & Gan, S. H. (2014). Determination of mineral, trace element, and pesticide levels in honey samples originating from different regions of Malaysia compared to Manuka honey. *BioMed Research International*, 2014. doi:10.1155/2014/359890
- Nanda, V., Sarkar, B. C., Sharma, H. K., & Bawa, A. S. (2003). Physico-chemical properties and estimation of mineral content in honey produced from different plants in Northern India. *Journal of Food Composition and Analysis*, 16(5), 613–619. doi:10.1016/S0889-1575(03)00062-0
- Perna, A., Simonetti, A., Intaglietta, I., Sofo, A., & Gambacorta, E. (2012). Metal content of southern Italy honey of different botanical origins and its correlation with polyphenol content and antioxidant activity. *International Journal of Food Science & Technology*, 47(9), 1909–1917. doi:10.1111/j.1365-2621.2012.03050.x
- Pisani, A., Protano, G., & Riccobono, F. (2008). Minor and trace elements in different honey types produced in Siena county (Italy). *Food Chemistry*, 107(4), 1553–1560. doi:10.1016/j.foodchem.2007.09.029
- Pohl, P. (2009). Determination of metal content in honey by atomic absorption and emission spectrometries. *TrAC Trends in Analytical Chemistry*, 28(1), 117–128. doi:10.1016/j.trac.2008.09.015
- Przybyłowski, P., & Wilczyńska, A. (2001). Honey as an environmental marker. *Food Chemistry*, 74(3), 289–291. doi:10.1016/S0308-8146(01)00153-4
- Rashed, M. N., & Soltan, M. E. (2004). Major and trace elements in different types of Egyptian mono-floral and non-floral bee honeys. *Journal of Food Composition and Analysis*, 17(6), 725–735. doi:10.1016/j.jfca.2003.10.004
- Rodríguez García, J. C., Iglesias Rodríguez, R., Peña Crecente, R. M., Barciela García, J., García Martín, S., & Herrero Latorre, C. (2006). Preliminary chemometric study on the use of honey as an environmental marker in Galicia (northwestern Spain). *Journal of Agricultural and Food Chemistry*, 54(19), 7206–7212. doi:10.1021/jf060823t
- Santos, J. S. D., Santos, N. S. D., Santos, M. L. P. D., Santos, S. N. D., & Lacerda, J. J. D. J. (2008). Honey classification from semi-arid, Atlantic and Transitional Forest Zones in Bahia, Brazil. *Journal of the Brazilian Chemical Society*, 19(3), 502–508. doi:10.1590/S0103-50532008000300018
- Sime, D., Atlabachew, M., Abshiro, M. R., & Zewde, T. (2015). Total phenols and antioxidant activities of natural honeys and propolis collected from different geographical regions of Ethiopia. *Bulletin of the Chemical Society of Ethiopia*, 29(2), 163–172. doi:10.4314/bcse.v29i2.1
- Stankovska, E., Stafilov, T., & Šajin, R. (2008). Monitoring of trace elements in honey from the Republic of Macedonia by atomic absorption spectrometry. *Environmental Monitoring and Assessment*, 142(1–3), 117–126. doi:10.1007/s10661-007-9913-x

Taddia, M., Musiani, A., & Schiavi, S. (2004). Determination of heavy metals in honey by Zeeman electrothermal atomic absorption spectrometry. *Annali Di Chimica*, 94(1-2), 107-111. doi:10.1002/adic.200490001

Üren, A., Şerifoğlu, A., & Sarkahya, Y. (1998). Distribution of elements in honeys and effect of a thermoelectric

power plant on the element contents. *Food Chemistry*, 61(1-2), 185-190. doi:10.1016/S0308-8146(97)00087-3

Wieczorek, J., Pietrzak, M., Pomianowski, J., & Wieczorec, Z. (2014). Honey as a source of bioactive compounds. *Polish Journal of Natural Science*, 29, 275-285.



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