GIAP Journals

Green Chemistry & Technology Letters
Vol 1, No 1, November 2015, pg 22-32
DoI: 10.18510/gctl.2015.114

COMPARATIVE ANALYSIS OF SOME MINERAL PROFILE OF HONEY MARKETED AND CONSUMED IN SOME OF THE STATES IN NORTHERN PART OF COUNTRY (NIGERIA)

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Article History: 02nd July, Revised on 05th October, Published on 05th November 2015

Abstract

Honey and honey trade is an important economic activity for many tropical rural and urban areas worldwide. In West Africa and other part of the world, honey and honey products holds high socio–cultural, religious, medicinal and traditional values. Therefore, to maximize benefits or to enhance profit, a variety of components are added to the raw, fresh and unprocessed honey, introducing the possibility of heavy metals contaminants. Therefore the honey sold in various places, markets and shops in some states in Northern Nigeria (Benue, Nassarawa and Taraba) including Abuja FCT, in Nigeria was analyzed to determine the level of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). All the honey samples contain heavy metals. The results ranged from 0.028–0.070, 0.023–0.058, 0.042–0.092, 4.231–8.589, 8.115–14.892, 0.078–0.922, 0.044–0.092, 0.041–0.087 and 18.234–28.654 µg/L for Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively. The mean concentration (µg/L) of the heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn of the regularly marketed honey is significantly higher than the mean concentration observed in raw, fresh and unprocessed honey. However, continued consumption of honey with high heavy metal content might lead to exposure to chronic heavy metal poisoning.

Keywords: Honey, health, mineral profile adulteration, contamination.

INTRODUCTION

Honey has been used since ancient times for a variety of health purposes, including healing, beauty, skin care and nutrition. Many types of honey are available on the market, but not all have the same healthy attributes [1].

In all of ancient history, honey has been a constant part of medicine. Honey has very high levels of antioxidants, comparable to the levels in spinach, apples and strawberries. Antioxidants are very important to our health because they rid our system of damaging free radicals that cause cell damage. There are so many more uses for honey other than in your tea or cereal [1]. The possible health benefits of consuming honey have been documented in early Greek, Roman, Vedic, and Islamic texts and the healing qualities of honey were referred to by philosophers and scientists all the way back to ancient times, such as Aristotle (384 - 322 BC) and Aristoxenus (320 BC) [2].

Honey has high levels of monosaccharide, fructose and glucose, containing about 70 to 80 percent sugar, which gives it its sweet taste - minerals and water make up the rest of its composition. Honey also possesses antiseptic and antibacterial properties. In modern science we have managed to find useful applications of honey in chronic wound management. However, it should be noted that many of honey's health claims still require further rigorous scientific studies to confirm them [3].

Honey has been consumed for thousands of years for its supposed health benefits. Over four thousand years ago, honey was used as a traditional ayurvedic medicine, where it was thought to be effective at treating material imbalances in the body [4].

In pre-Ancient Egyptian times, honey was used topically to treat wounds. Egyptian medicinal compounds more than five millennia ago used honey. The ancient Greeks believed that consuming honey could help make you live longer [5].

The beneficial properties of honey have been explored in modern times, and there is evidence to suggest that these historical claims may hold some truth. Honey is made up of glucose, fructose, and minerals such as iron, calcium, phosphate, sodium chlorine, potassium, magnesium. The slightly acidic pH level of honey (between 3.2 and 4.5) is what helps prevent the growth of bacteria, while its antioxidant constituents clean up free radicals. The physical properties of honey vary depending on the specific flora that was used to produce it, as well as its water content [6].Scientists have revealed that honey has powerful anti-bacterial properties on at least sixty species of bacteria, and unlike antibiotics, which are often useless against certain types of bacteria; honey is non-toxic and has strong effects. [6] The composition of honey includes sugars such as glucose and fructose and also minerals such as magnesium, potassium, calcium, sodium chloride, sulphur, iron and phosphate. Depending on the quality of the nectar and pollen, the vitamins contained in honey are B1, B2, C, B6, B5 and B3.[6]

The pH of honey is commonly between 3.2 and 4.5. [7] This relatively acidic pH level prevents the growth of many bacteria. Honey is primarily a saturated mixture of two monosaccharides. This mixture has a low water activity. Most of the water molecules are associated with the sugars and few remain available for microorganisms, so it is a poor environment for their growth. If water is mixed with honey, it loses its low water activity, and therefore, no longer possesses this antimicrobial property. More importantly, its undiluted state, honey's high osmolarity creates a hygroscopic effect on microbes, thereby interfering with growth and metabolism. Such hygroscopic activity has led some to use granulated sugar or other sugar concentrates for the same purpose. Nevertheless, the antimicrobial action of honey well exceeds a simple osmotic effect, and an equivalent osmolarity of various sugars does not match honey's antimicrobial capability.] Hydrogen peroxide is formed in a slow –release manner by the enzyme glucose oxidase present in honey. It becomes active only when honey is diluted, requires oxygen to be available for the reaction, thus it may not work under wound dressings, in wound cavities or in the gut. It is active only when the acidity of honey is neutralised by body fluids, it can be destroyed by the protein-digesting enzymes present in wound fluids, and is destroyed when honey is exposed to heat and light. Honey chelates and deactivates free iron, which would otherwise catalyse the formation of oxygen free radicals from hydrogen peroxide, leading to inflammation. Also, the antioxidant constituents in honey help clean up oxygen free radicals.[7]

$C6H12O6 + H2O + O2 \rightarrow C6H12O7 + H2O2$ (glucose oxidase reaction)

When honey is used topically, as, for example, a wound dressing, hydrogen peroxide is produced by dilution of the honey with body fluids. As a result, hydrogen peroxide is released slowly and acts as an antiseptic [8]. The benefits of honey have been extolled since ancient times by many religious faiths and recorded in ancient scriptures. They can be categorised as nutritional or medicinal. Nutritional; Honey contains invert sugar that has the quality of providing instant energy when consumed. It is also a heart stimulant and a useful food supplement. As a food beverage, it was widely used from the times of "the Bible (both the [Old Testament] and New Testament(s)), the Talmud, the Quran, the sacred books of India, China, Persia and Egypt [9]."

Medicinal benefits topical honey has been used successfully in a treatment of diabetic ulcers when the patient cannot use topical antibiotics. Antibacterial properties of honey are the result of the low water activity causing osmosis, hydrogen peroxide effect, high acidity, and the antibacterial activity of methylglyoxal. Wound gels that contain antibacterial raw honey and have regulatory approval for wound care are now available to help medicine in the battle against drug resistant strains of bacteria MRSA. As an antimicrobial agent honey may have the potential for treating a variety of ailments. Some studies suggest that the topical use of honey may reduce odours, swelling, and scarring when used to treat wounds; it may also prevent the dressing from sticking to the healing wound. Allergies ;It is also stated to cure some allergies, particularly localized honey to an area could help minimize seasonal allergies as bees feed on pollen from local plants which eventually finds its way to form honey. Its use for centuries is as a treatment for sore throats and coughs, and according to recent research, may in fact be as effective as many common cough medicines.[10,11]

Other ailments Antioxidants in honey have even been implicated in reducing damage to the colon in colitis in a study involving administering honey enemas to rats.[26=16] Honey appears to be effective in killing drug-resistant biofilms which are implicated in chronic rhinosinusitis. Honey is used for skin conditioning using a moisturizing mask and can reduce facial redness and acne. It is also used for conditioning of hair. It is often mixed with olive oil or castor oil for both purposes [11].

Interestingly, both government and health professionals have recognized health benefits of honey in the treatment and prevention of malnutrition and vitamin A deficiency diseases [10]. The benefits of honey have been extolled since ancient times by many religious faiths and recorded in ancient scriptures. They can be categorised as nutritional or medicinal. Honey contains invert sugar that has the quality of providing instant energy when consumed. It is also a heart stimulant and a useful food supplement. As a food beverage, it was widely used from the times of "the Bible (both the [Old Testament] and New Testament(s)), the Talmud, the Quran, the sacred books of India, China, Persia and Egypt."Medicinal benefits are many. Topical honey has been used successfully in a treatment of diabetic ulcers when the patient cannot use topical antibiotics. Antibacterial properties of honey are the result of the low water activity causing osmosis, hydrogen peroxide effect, high acidity, and the antibacterial activity of methylglyoxal [12, 13]. Some studies suggest that the topical use of honey may reduce odours, swelling, and scarring when used to treat wounds; it may also prevent the dressing from sticking to the healing wound. Wound gels that contain antibacterial raw honey and have regulatory approval for wound care are now available to help medicine in the battle against drug resistant strains of bacteria. As an antimicrobial agent honey may have the potential for treating a variety of ailments. It is also stated to cure some allergies; particularly localized honey to an area could help minimize seasonal allergies as bees feed on pollen from local plants which eventually find its way to form honey. Its use for centuries is as a treatment for sore throats and coughs, and according to recent research, may in fact be as effective as many common cough medicines [14]. Scientists have revealed that honey has powerful anti-bacterial properties on at least sixty species of bacteria, and unlike antibiotics, which are often useless against certain types of bacteria; honey is non-toxic and has strong effects. The composition

Green Chemistry & Technology Letters
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of honey includes sugars such as glucose and fructose and also minerals such as magnesium, potassium, calcium, sodium chloride, sulphur, iron and phosphate. Depending on the quality of the nectar and pollen, the vitamins contained in honey are B1, B2, C, B6, B5 and B3 [14, 15, and 16].

Although honey remain vital in many activities, human nutrition and medicinal treatment, we are concerned about its adulteration and contamination by toxic elements and the potential risk such contamination could pose to the consumers in societies. In recent times, however, honey has been undergoing a kind of transformation. Honey serves as a source of income to both tappers and vendors who for the sake of maximizing their profit margin engage in various forms of manipulations to the honey which leads to adulteration of the product. Honey is diluted with water by vendors and to maintain the required taste, substances such as sugar and other chemical additives is added. Some of the consequential product of adulteration is presumed to contain salicylate and high heavy metal content. Heavy metal is known to have toxic effect at a certain level of exposure. Once ingested, heavy metals can't be metabolized or eliminated through normal means. Once they are in your body you can't get them out unless you make a conscious, concerted effort to do so.

Removing them takes time, effort, and costs money. This additive, according to experts, is capable of causing health challenges, which may result in diarrhoea, dysentery or runny stomach. It is even more dangerous with people suffering from diabetics [17,18, and 19].

Unfortunately, most of the research on honey is in medicinal, microbiology and economics papers. Although the Food and Agriculture Organization (FAO) has shown great interest in the nutritional and medicinal value of honey products, there is little mention of it in public health literature [20, 21, and 22]. To the best of our knowledge no study has been conducted in our environment to evaluate the concentration of heavy metals present in the honey and the potential hazards such contamination may pose to human health. It is possible that these heavy metals could have access into honey during tapping or harvesting, processing, packaging, storage sale of the product or intentional addition by the producer or marketer [23, 24]. The presence of these toxic metals may appear harmless in minute quantities, however their accumulation over time carries potential health risk to human who regularly consume or uses of honey and honey products contaminated with toxic metals [25, 26,]. Therefore, it has become imperative to assess the levels of heavy metals in honey sold in different markets and outlets in some state in Northern part of Nigeria. Based on the high production and consumption of honey in some states in Northern Nigeria (WHO, 2001), coupled with the fact that some unscrupulous retailers use various chemicals of unknown composition for the artificial production of honey; this study was designed to identify possible products of honey containing some potential heavy metal contamination. The study examined the occurrence and the concentrations of toxic metals: cadmium, cobalt, chromium, copper, iron, and manganese, nickel, lead and zinc in the honey produced, market and consumed in some of the states in Northern part of Nigeria.

MATERIALS AND METHODS

Sample collection

A total of sixty samples of honey (n = 60) were obtained from three different states including Abuja (FCT) in Northern part of the country where honey are produced and market in the large quantity. The three states are Benue, Nassarawa , Taraba and Abuja (FCT) of Nigeria and twelve freshly tapped samples (n =12) served as controls. Sample were collected into sterile containers and brought to the laboratory for trace heavy metal analysis.

Statistical analysis

Microsoft Excel (2007) package was used for statistical analysis employing the independent sample t-test. Summary statistics such as mean, standard deviation (SD) and correlation were computed. Significant tests were carried out at the 0.05 level of significance. It is concluded that there is significant difference if the probability associated with the t test (p) is less than the level of significance (that is, $p < 0.05$).

RESULTS AND DISCUSSION

The concentrations of the various heavy metals found in the honey samples are presented in tables 1, 2, 3, 4. Table 1 represent the honey samples bought from various shops and other retailers in Abuja metropolis, table 2 represent same sample bought from Benue state, table 3 represent the honey samples bought from Nassarawa state, table 4 represent the same samples from Taraba state, table 5 represent the control samples from each of the study areas and table 6 is the summary of the whole results with the control values. Control was the direct raw, fresh, unprocessed honey which was obtained from the honey taper from the remote village of each the

study areas. The result revealed clear elevated levels of these heavy metals Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn determined in the honey samples from various markets, shops and other retailers in each of the study areas. The mean concentration of heavy metals obtained from the control (direct direct raw, fresh, unprocessed honey) was consistently low, much lower than those obtained from the honey sample under consideration. This reflects a general contamination of the honeys by the heavy metals studied. The results also showed higher degree of heavy metal contamination of honeys bought from various shops, markets and other retailers by the heavy metals studied. All the heavy metals considered Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn showed the high of contamination in the honey samples purchased from various markets. The overall results ranged from 0.028–0.070, 0.023–0.058, 0.042–0.092, 4.231–8.589, 8.115–14.892, 0.078–0.922, 0.044–0.092, 0.041–0.087 and 18.234–28.654 µg/L for Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively. The concentration of all the trace heavy metals determined in the honey (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) were higher in all the honey samples bought from various shops and supermarkets in the study areas when compared with the corresponding values for raw, fresh and unprocessed honey i.e. control (table 5). Cd, Ni and Pb were detected in all the honey samples analyzed. However, Cd, Ni and Pb were not detected in raw, fresh and unprocessed honey.

The qualitative similarity of the heavy metals in the honey samples is an indication that the materials for honey dilution and contamination really the same or similar in all the areas the honey samples were collected for the analysis. Because of the complicated pattern in the concentration relationship of the samples, focusing on the comparison between the honey products will be futile, instead, the general profile of each heavy metal will be discussed focusing attention to any anomaly. The little discrepancies in the differing quantitative pattern among the samples were expected. The reason may hinge on several factors. For instance, heavy metal levels of honey depends on the level of metal contaminants in the harvesting, processing, packaging and storage containers and environmental contamination of the areas, soil amendment and soil Ph [20, 21]. Also, metal absorption for a variety of honey products has been shown to be dependent on geographical origin [22]. Therefore among factors which may account for these differences in elemental concentrations are: the geographical or the geology of the area on where the honey were tapped; different climatic conditions and hence different environments; and also the dilution materials in terms of other chemical additives during the production and dilution processes. Honey comes in many varieties, depending on the floral source of pollen or nectar gathered and regurgitated by the honey bee upon arrival in the hive.

Therefore follows from results (Table 1,2, 3 and 4), the presence of elements like Cd, Co, Cr, Ni, and Pb indicated that the nature of honey could be carcinogenic [18]. The carcinogenicity nature from observation has no correlation from the geographical origin of the honey raw material. Even though trace heavy metals present in honey do not entirely determine the risk likely to be caused by honey consumptions, they can become more hazardous where they are present in higher concentrations, and could lead to higher health risk. Special attention has been given to the elements that play a significant toxicological role after entering the human body through honey consumption or uses of other honey products. Contamination of the honey with heavy metals could pose potential health risk to humans and animals because these heavy metals have the ability to "bio-accumulate". Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Reports from previous research have shown that compounds accumulate in living things any time they are taken up and stored faster than they are broken (metabolized or excreted) [18,19]. For instance, research has shown that significant flux of heavy metal, among other toxins, reach the lungs through the consumption of contaminated foods, either honey or uses of honey products.

All the honey samples contained detectable amounts of these heavy metals of interest. Pb, a ubiquitous and versatile metal was also detected in all the samples. It has become widely distributed and mobilized in the environment and human exposure to and uptake of this non-essential element has consequently increased [20]. At high levels of human exposure, there is damage to almost all organs and systems, most importantly the central nervous system, kidneys and blood, culminating in death at excessive levels. At low levels, haem synthesis and other biochemical processes have been reported to be affected by lead contamination [21, 22]. Lead continues to be a significant public health problem in developing countries where there are considerable variations in the sources and pathways of exposure, therefore care need to be taking in the consumption of Pb contaminated honey and honey products since Pb exposure is through direct contact. It was investigated and it has been shown that exposure to Pb can lead to a wide range of biological defects in human depending on duration and level of exposure. The developing foetus and infants are far more sensitive than adults. High exposure can cause problems in the synthesis of haemoglobins, damage to the kidneys, gastrointestinal tract, joints, reproductive system and the nervous system. Cadmium also was detected in the honey samples in various concentrations and cadmium when ingested by humans; it accumulates in the intestine, liver and kidney [21]. The health effects of chronic exposure of Cd include proximal tubular disease and osteomalacia. Long term exposure to cadmium is associated with renal dysfunction. Cadmium is bio persistent and once absorbed remains resident for many years. High exposure can lead to obstructive lung diseases and has been linked to lung cancer. Cadmium may also cause bone defects in humans and animals. The average daily intake for humans is estimated as

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0.15µg from air and 1µg from water [23]. Maximum limit of 0.2 µg/g Cd in plant and 5.0 µg/g Pb in plant was prescribed by WHO/FAO[24]. The values for the standard compared to our work indicate Cd pollution of some the honey samples analyzed in the study areas. Chromium is considered non-essential for plants, but an essential element for animals. The average abundance of Cr in the earth's crust is 122 ppm; in soils Cr ranges from 11-22 ppm [18,25]. Cr toxicity in man has been limited to haemorrhage, respiratory impairment and liver lesions [18]. Low exposure to chromium can irritate the skin and cause ulceration. Long term exposure can cause kidney and liver damage. It can also cause damage to circulatory and nerve tissues. In this work, Cr was found to ranged between 0.042 – 0.092 µg/g with an average of 0.069±0.012 µg/g. This value is less than 150 µg/g safe limits giving by EU commission regulation [18] Cr concentration in this study is lower than 0.10 µg/g maximum limit set by WHO/FAO [27]. Levels of Ni in all the honey sample products analyzed from each the study areas were almost similar, the slight differences in their concentration were statistically not significant ($p<0.5$). The mean Ni concentration in the sample products (0.061±0.011 µg/g). It is important to note that Ni concentrations in all the honey samples investigated were lower than what was obtained by other researchers in the similar studies [26]. Nickel apparently has a limited acute toxicity in humans, including airway irritation, but the important adverse effects relate to allergic eczema and respiratory cancers [18, 26]. Excessive amounts of nickel can be mildly toxic. Long term exposure can cause decreased body weight, heart and liver damage and skin irritation; the symptoms of exposure to some poisonous nickel compounds include nausea, vomiting, headaches and sleeplessness. The symptoms get worse later on from 12 to 24 hours after exposure and include a speeding heart, difficult breathing, chest pains and extreme fatigue.

The mean levels of Co and Cu in the samples studied was 0.040±0.009 and 6.124±1.023 µg/g. The average Fe concentration (11.722±1.274 µg/g) was obtained in the honey samples studied .Copper, cobalt and iron are classified as essential to life due to their involvement in certain physiological processes, but elevated levels of these elements, however, have been found to be toxic. Copper, Fe and Co form the essential group of metals required for some metabolic activities in organisms. Toxicological effects of large amounts of Co include vasodilatation, flushing and cardiomyopathy in humans and animals and high doses of copper can cause anaemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from over exposure to copper. Mn concentration in all the samples studied ranged from 0.078 – 0.922 µg/g and higher concentration of Mn was detected in the honey samples sold in markets. Manganese is known to block calcium channels and with chronic exposure results in CNS dopamine depletion. This duplicates almost all of the symptomology of Parkinson's disease.

According to the mean and range values (Table 6) of the Co, Cu, Fe and Mn in the all samples of honey studied revealed that the levels of these metals were lower than the limit level for standard for World Health Organization [24].

The mean concentration of Zn in the honey samples analyzed ranges from 18.234 – 28.654 µg/g. Thus in the present study, the highest amount of Zn found in the samples is much lower than the permissible level of 250: µg/g [22, 24]. However, these values are similarly related to those reported in several studies [25, 26, and 30]. Although humans can handle proportionally large concentrations of zinc, too much zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis [27]. From the range and mean values, there is a clear indication that the honey and honey products sold in the various places including shops and supermarkets in three different states in Northern parts of Nigeria including Abuja (FCT) contained trace heavy metals in various concentrations higher than the level in fresh, raw and unprocessed honeys. There was however no appreciable difference in the concentration of heavy metals in all the various honey samples studied. Analysis of Variances (ANOVA) showed a significant difference ($P<0.05$) between the concentration of heavy metals in the all the honey samples sold in the various markets and fresh, raw and unprocessed honey tapped from direct sources. The mean value of heavy metal concentrations of the regularly sold honey is significantly higher than mean value concentrations observed in freshly raw tapped honey.

All the samples contained these heavy metals. Honey serves as a source of income to both honey tappers and vendors who for the sake of maximizing their profit margin engage in various forms of manipulations to the honey which leads to adulteration of the product. The sources of these heavy metals in the honey samples from different states in Northern part of the country may be attributed to harvesting, processing, packaging, storage containers, dilution with contaminated water and other chemical additives to the original honey products in order to increase the quantity, although this is often denied or even masked by addition of artificial sweeteners and other local additive. Indeed one of the most frequent complaints of honey consumers is the adulteration of the product by use of water and artificial sweeteners, which sometimes result in diarrhoea, abdominal pains and stomach problems [28]. Unguided business behaviour and lack of effective monitoring of product quality lead to heavy metal contamination of honeys.

Pearson correlation among heavy metals in the honey sample products was calculated to see if some metals were interrelated with each other and the results are presented in Table 7. Correlation study of the data indicated a weak correlation between some metals determined. Zn/Pb, Zn/Ni and Cu/Mn shown positive correlation, while Co/Cu is negatively correlated.

Although all the trace heavy metal determined were present in all the honey samples analyzed but the present concentrations may not pose any serious health hazard but attention should be given Cd, Ni and Pb that were presented in honey from various markets but not in the honey from control. All parameters examined in the honey samples have values that are below or within the maximum permissible limit of WHO, FAO and EC Standards, hence the present result may not pose any serious health hazard, but attention should be given to Cd and Pb could be harmful to human after prolong exposure to these pollutants even at lower concentration. Therefore maintaining this symbolic commodity of immense health values in its original unadulterated form for consumption is advocated.

CONCLUSION

A comprehensive study of the some heavy metal distributions in honey product marketed in some of the states in Northern Nigeria including Abuja (FCT) has been completed. Nine trace heavy metals have been determined for all the samples. Regularly sold honey contained all the heavy metals determined in various concentrations. The presence of some of these heavy metals (Cd, Ni, and Pb) in the regularly sold honey as opposed to the freshly, raw and unprocessed tapped honey is certainly a result of adulteration of the product. The study is of the view that the continuous use of some of the honey and honey products could result in an increase in heavy and trace metals in the human body beyond acceptable limits through accumulation. Moreover, honey and honey products have provided basic materials for health benefits of popular foods. Honey also possesses antiseptic and antibacterial properties. It is used in traditional medicine and the most important potential health benefits of food and drink in most part of the world. Honey has been consumed for thousands of years for its supposed health benefits. It is thus a commodity with economic, religious, social and cultural value and hence should be maintained in its original unadulterated form. To avoid heavy metals poisoning and high heavy metal intake, we advocate consumption of freshly tapped, unadulterated honey.

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Table 1: Total Heavy Metal contents (µg/g) in honey market and consumed in Abuja metropolis

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	0.063	0.045	0.056	5.432	12.511	0.122	0.045	0.052	21.231
2	0.052	0.055	0.042	4.231	12.321	0.131	0.065	0.047	21.971
3	0.042	0.043	0.062	7.653	11.975	0.765	0.055	0.042	19.554
4	0.035	0.044	0.071	6.788	12.245	0.144	0.067	0.051	18.767
5	0.055	0.051	0.082	5.678	12.331	0.175	0.061	0.043	21.876
6	0.061	0.055	0.068	6.133	11.859	0.166	0.067	0.048	19.997
7	0.043	0.052	0.057	5.699	12.222	0.098	0.092	0.051	25.543
8	0.045	0.047	0.071	6.589	11.789	0.144	0.077	0.056	26.234
9	0.057	0.048	0.065	4.321	12.208	0.089	0.054	0.061	25.543
10	0.061	0.043	0.059	7.431	12.156	0.201	0.071	0.049	18.675
11	0.053	0.058	0.066	4.444	11.999	0.078	0.055	0.054	27.654
12	0.048	0.054	0.079	5.333	12.115	0.132	0.045	0.052	26.098

13	0.052	0.052	0.068	4.237	12.101	0.141	0.065	0.043	19.123
14	0.049	0.051	0.059	5.387	11.892	0.211	0.081	0.061	20.543
15	0.053	0.058	0.073	5.298	12.401	0.171	0.055	0.048	19.987
Mean	0.051	0.050	0.065	5.644	12.142	0.185	0.064	0.051	22.186
STD	0.008	0.005	0.010	1.107	0.209	0.165	0.013	0.006	3.138
MIN	0.035	0.043	0.042	4.231	11.789	0.078	0.045	0.042	18.675
MAX	0.063	0.058	0.082	7.653	12.511	0.765	0.092	0.061	27.654

Table 2: Total heavy metal contents (µg/g) in honey market and consumed in Benue state

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	0.076	0.035	0.057	5.112	10.511	0.922	0.085	0.055	22.123
2	0.063	0.045	0.059	6.955	12.521	0.831	0.055	0.065	24.971
3	0.042	0.033	0.049	4.856	10.975	0.701	0.065	0.055	23.554
4	0.035	0.034	0.075	4.788	12.245	0.744	0.057	0.067	25.065
5	0.045	0.041	0.056	6.678	11.331	0.875	0.051	0.061	27.876
6	0.065	0.045	0.088	5.835	12.859	0.666	0.077	0.057	19.997
7	0.075	0.042	0.045	5.699	9.222	0.698	0.082	0.062	23.543
8	0.054	0.037	0.075	6.589	11.789	0.844	0.067	0.077	18.234
9	0.048	0.038	0.067	6.023	11.208	0.689	0.044	0.054	24.543
10	0.053	0.033	0.073	7.011	10.156	0.801	0.061	0.071	20.675
11	0.063	0.048	0.092	6.955	13.999	0.788	0.045	0.055	26.654
12	0.028	0.044	0.088	4.654	8.115	0.732	0.075	0.075	22.098
13	0.067	0.042	0.075	7.896	11.101	0.841	0.055	0.065	27.012
14	0.057	0.041	0.077	7.105	14.892	0.887	0.071	0.081	22.122
15	0.033	0.048	0.054	6.786	13.401	0.771	0.065	0.075	19.987
Mean	0.054	0.040	0.069	6.196	11.622	0.786	0.064	0.065	23.230
STD	0.015	0.005	0.015	1.000	1.786	0.080	0.013	0.009	2.830
MIN	0.028	0.033	0.045	4.654	8.115	0.666	0.044	0.054	18.234
MAX	0.076	0.048	0.092	7.896	14.892	0.922	0.085	0.081	27.876

Table 3: Total heavy metal contents (µg/g) in honey market and consumed in Nassarawa state

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	0.043	0.025	0.089	6.987	10.511	0.122	0.066	0.051	19.123
2	0.065	0.035	0.066	5.897	11.321	0.131	0.073	0.051	21.971
3	0.032	0.023	0.077	6.856	10.375	0.201	0.052	0.042	23.554
4	0.044	0.024	0.058	5.788	12.245	0.144	0.061	0.044	21.011
5	0.062	0.031	0.082	4.678	9.331	0.175	0.052	0.043	19.876
6	0.051	0.035	0.081	6.835	10.459	0.166	0.054	0.065	22.997
7	0.042	0.032	0.062	7.699	10.222	0.098	0.061	0.055	28.543
8	0.061	0.027	0.081	5.589	11.389	0.144	0.055	0.042	26.234
9	0.033	0.028	0.073	6.543	12.208	0.089	0.062	0.052	21.543
10	0.055	0.023	0.068	4.453	11.256	0.201	0.051	0.041	19.675
11	0.052	0.038	0.075	6.555	12.299	0.321	0.052	0.053	24.654

12	0.044	0.034	0.053	7.567	13.211	0.132	0.054	0.055	27.098
13	0.061	0.032	0.084	5.896	11.21	0.141	0.046	0.061	19.133
14	0.052	0.031	0.059	6.762	13.292	0.122	0.052	0.041	27.098
15	0.065	0.038	0.073	5.786	10.241	0.171	0.045	0.048	20.987
Mean	0.051	0.030	0.072	6.259	11.305	0.157	0.056	0.050	22.900
STD	0.011	0.005	0.011	0.939	1.156	0.056	0.008	0.008	3.158
MIN	0.032	0.023	0.053	4.453	9.331	0.089	0.045	0.041	19.123
MAX	0.065	0.038	0.089	7.699	13.292	0.321	0.073	0.065	28.543

Table 4: Total heavy metal contents (µg/g) in honey market and consumed in Taraba state

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	0.056	0.035	0.057	7.112	13.511	0.922	0.075	0.075	22.123
2	0.063	0.045	0.059	6.955	12.521	0.831	0.055	0.065	23.971
3	0.062	0.033	0.049	5.856	9.975	0.701	0.065	0.075	25.554
4	0.055	0.034	0.085	6.788	11.245	0.744	0.057	0.067	25.065
5	0.045	0.041	0.056	5.678	10.331	0.875	0.051	0.061	21.876
6	0.065	0.045	0.088	6.835	12.859	0.666	0.067	0.087	19.997
7	0.065	0.042	0.065	7.699	10.222	0.698	0.062	0.062	27.543
8	0.054	0.037	0.075	8.589	11.789	0.844	0.067	0.077	21.234
9	0.048	0.038	0.067	5.023	13.208	0.689	0.044	0.054	23.543
10	0.053	0.033	0.073	5.011	10.156	0.801	0.061	0.071	25.675
11	0.063	0.048	0.092	5.955	13.999	0.788	0.055	0.055	28.654
12	0.048	0.044	0.088	6.654	11.115	0.732	0.075	0.085	22.098
13	0.067	0.042	0.075	5.896	12.101	0.841	0.055	0.065	21.012
14	0.057	0.041	0.077	6.105	10.892	0.887	0.071	0.081	19.122
15	0.053	0.048	0.054	5.786	13.401	0.771	0.065	0.075	27.987
Mean	0.057	0.040	0.071	6.396	11.822	0.786	0.062	0.070	23.697
STD	0.007	0.005	0.014	0.973	1.371	0.080	0.009	0.010	2.968
MIN	0.045	0.033	0.049	5.011	9.975	0.666	0.044	0.054	19.122
MAX	0.067	0.048	0.092	8.589	13.999	0.922	0.075	0.087	28.654

Table 5: Total heavy metal contents (µg/g) in fresh,raw unprocessed honey from the study areas (Control)

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	N.D	0.015	0.017	3.112	6.511	0.222	N.D	N.D	11.123
2	N.D	0.005	0.019	2.955	5.521	0.231	N.D	N.D	11.971
3	N.D	0.013	0.009	2.856	4.975	0.201	N.D	N.D	11.554
4	N.D	0.014	0.015	3.788	5.245	0.244	N.D	N.D	11.065
1	N.D	0.012	0.015	3.412	5.511	0.212	N.D	N.D	10.423
2	N.D	0.011	0.010	2.050	5.521	0.201	N.D	N.D	10.571
3	N.D	0.018	0.013	2.856	4.675	0.291	N.D	N.D	10.654
4	N.D	0.010	0.015	3.384	5.045	0.211	N.D	N.D	10.065

1	N.D	0.013	0.016	3.112	4.511	0.301	N.D	N.D	10.123
2	N.D	0.008	0.012	2.852	5.521	0.251	N.D	N.D	9.971
3	N.D	0.013	0.011	2.856	4.475	0.251	N.D	N.D	10.754
4	N.D	0.017	0.015	3.086	5.345	0.214	N.D	N.D	9.065
1	N.D	0.015	0.018	3.112	5.512	0.321	N.D	N.D	11.323
2	N.D	0.009	0.011	2.955	5.521	0.300	N.D	N.D	10.971
3	N.D	0.011	0.014	2.756	4.875	0.301	N.D	N.D	10.554
4	N.D	0.016	0.015	3.488	5.645	0.244	N.D	N.D	9.965
MEAN	N.D	0.013	0.014	3.039	5.276	0.250	N.D	N.D	10.635
STD	N.D	0.003	0.003	0.387	0.511	0.041	N.D	N.D	0.714
MIN	N.D	0.005	0.009	2.05	4.475	0.201	N.D	N.D	9.065
MAX	N.D	0.018	0.019	3.788	6.511	0.321	N.D	N.D	11.971

Table 6: Summary of the total heavy metal in the honey samples from the study areas

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Abuja									
MEAN	0.051	0.050	0.065	5.644	12.142	0.185	0.064	0.051	22.186
STD	0.008	0.005	0.010	1.107	0.209	0.165	0.013	0.006	3.138
MIN	0.035	0.043	0.042	4.231	11.789	0.078	0.045	0.042	18.675
MAX	0.063	0.058	0.082	7.653	12.511	0.765	0.092	0.061	27.654
Benue									
MEAN	0.054	0.040	0.069	6.196	11.622	0.786	0.064	0.065	23.230
STD	0.015	0.005	0.015	1.000	1.786	0.080	0.013	0.009	2.830
MIN	0.028	0.033	0.045	4.654	8.115	0.666	0.044	0.054	18.234
MAX	0.076	0.048	0.092	7.896	14.892	0.922	0.085	0.081	27.876
Nassarawa									
MEAN	0.051	0.030	0.072	6.259	11.305	0.157	0.056	0.050	22.900
STD	0.011	0.005	0.011	0.939	1.156	0.056	0.008	0.008	3.158
MIN	0.032	0.023	0.053	4.453	9.331	0.089	0.045	0.041	19.123
MAX	0.065	0.038	0.089	7.699	13.292	0.321	0.073	0.065	28.543
Taraba									
MEAN	0.057	0.040	0.071	6.396	11.822	0.786	0.062	0.070	23.697
STD	0.007	0.005	0.014	0.973	1.371	0.080	0.009	0.010	2.968
MIN	0.045	0.033	0.049	5.011	9.975	0.666	0.044	0.054	19.122
MAX	0.067	0.048	0.092	8.589	13.999	0.922	0.075	0.087	28.654
AII THE SAMPLES									
MEAN	0.053	0.040	0.069	6.124	11.722	0.478	0.061	0.059	23.003
STD	0.011	0.009	0.012	1.023	1.274	0.326	0.011	0.012	3.000
MIN	0.028	0.023	0.042	4.231	8.115	0.078	0.044	0.041	18.234
MAX	0.076	0.058	0.092	8.589	14.892	0.922	0.092	0.087	28.654
Control									
MEAN	N.D	0.013	0.014	3.039	5.276	0.250	N.D	N.D	10.635

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DoI: 10.18510/gctl.2015.114

STD	N.D	0.003	0.003	0.387	0.511	0.041	N.D	N.D	0.714
MIN	N.D	0.005	0.009	2.050	4.475	0.201	N.D	N.D	9.065
MAX	N.D	0.018	0.019	3.788	6.511	0.321	N.D	N.D	11.971

Table 7: Inter elemental correlation between the trace heavy metals studied

Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		0.171	-0.132	-0.285	0.227	-0.291	-0.335	0.012	-0.080
			0.113	-0.671	-0.010	-0.426	-0.057	-0.012	0.343
				0.134	-0.133	-0.056	-0.264	-0.101	0.116
					-0.266	0.592	0.212	-0.228	-0.386
						-0.250	-0.371	-0.236	-0.180
							-0.121	-0.433	-0.383
								0.154	0.500
									0.500
		0.066	-0.087	0.319	0.074	0.274	0.258	-0.372	0.086
			0.251	0.375	0.340	-0.085	-0.091	0.088	0.116
				0.122	0.234	-0.059	-0.166	0.192	-0.089
					0.471	0.450	-0.441	0.259	0.160
						0.227	-0.318	0.116	0.112
							0.000	0.300	0.112
								0.198	-0.604
									-0.467
		0.470	0.181	-0.608	-0.205	0.177	-0.241	-0.030	-0.227
			-0.084	0.222	0.044	0.218	-0.175	0.546	0.250
				-0.247	-0.619	0.202	-0.147	0.175	-0.526
					0.270	-0.251	0.234	0.480	0.612
						-0.041	0.061	-0.049	0.393
							-0.423	-0.097	-0.081
								0.052	0.017
									0.008
		0.222	0.125	0.269	0.135	-0.154	0.060	0.002	0.117
			0.236	0.027	0.482	-0.085	-0.050	-0.033	0.125
				0.129	0.164	-0.204	0.089	0.156	-0.176
					0.009	0.090	0.450	0.311	-0.178
						0.069	0.450	-0.153	0.084
							0.163	-0.008	-0.347
								0.861	-0.267
									-0.493