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Determination of concentration of heavy metals in ginger using flame atomic absorption spectroscopy

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Concentrations of four heavy metals (Ni, Zn, Cd and Pb) in two ginger varieties were determined using flame atomic absorption spectroscopy (FAAS) with wet acidic digestion methods. Results showed that the concentration of zinc is 0.86 to 1.17 mg/kg in Hargama and 0.63 to 0.87 mg/kg in Bolbo varieties. The concentration of nickel for Hargama and Bolbo are 0.15 to 0.18 and 0.17 to 0.21 mg/kg, respectively. Zinc concentration in Hargema variety is statistically significantly different from Bolbo variety. However, no statistically significant differences were observed in nickel concentrations. Concentration of zinc is relatively greater than concentration of nickel in the samples. Concentrations of both metals are below permissible limits set by WHO/FAO and could not cause health problems. In addition to this, the concentration level of both metals is lower than toxicity levels. But concentrations of cadmium and lead metals were below the method detection limit.

Key words: Concentration, ginger, heavy metal, permissible limit, toxicity.

INTRODUCTION

Ginger is a medicinal herb and belongs to Zingiberaceae family, genus *Zingiber* and species *officinale* (Gupta and Sharma, 2014). It is widely used as a spice and medical treatment for certain diseases. Ginger contains several compounds and its major components are 6-gingerol, 6-shogaol, and 6-paradol that possess strong antioxidant activity (Prasad and Tyagi, 2015) and it possesses health benefits. Ginger also contains different nutrients such as protein, fats, insoluble fibers, soluble fibers, carbohydrates and vitamins (Shirin and Jamush, 2010; Ajayi et al., 2013).

Spices contain essential elements like Na, K, Cu, Zn, Ca, Mg, Fe and Mn as well as non-essential or toxic elements such as Hg, Cd, Pb and Cr metals (Longhurst, 2010; Belay and Tadesse, 2014). Low intake of essential metals produces deficiencies, while higher consumption may cause toxicity. However, non-essential metals are lethal and toxic to human even at low concentrations.

Non-essential metals are ranked among the most hazardous toxic substances owing to their persistence in the environment and absorption in food chain (Khan et al., 2013; Muhammad et al., 2013). Toxic effects of metals include vomiting, diarrhea, headache, irritability, hypertension, heart, lung, kidney, liver and intellectual

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problems and cancer (Shah and Ara, 2012). Toxic metals are extremely persistent in the environment even at low concentrations and have been reported to produce damaging effects on human and animals because there is no good mechanism for their elimination from the body (Loannidou et al., 2005; Adah et al., 2013).

There is evidence that lead pollution can induce aggressive behavior in animals which can also occur in humans (Nkansah and Amoako, 2010). Krejpcio et al. (2007) reported that concentration of zinc in spices from Polish markets is found to be 5.96 to 16.95 mg/kg while Nkansah and Amoako (2010) researched that the concentration of zinc in spices from Ghana is found to be 73 g/kg. Wagesho and Chandravanshi (2015) indicated that the concentration of zinc in some parts of Ethiopian ginger is 38.5 to 55.2 mg/kg. Agrawal et al. (2011) reported that the concentration of zinc is 0.46 to 2.74 mg/kg while Devi et al. (2008) showed that the concentration of zinc is 44.93 mg/kg in Indian spices.

The contents of trace metals in herbal medicinal plants from Turkey are found in the ranges: 0.2 to 2.7 μg/g for cadmium, 0.1 to 2.8 μg/g for lead, 1.4 to 11.3 μg/g for nickel and 5.2 to 83.7 μg/g (Soylak et al., 2006). According to result of Komy (2005), concentration of lead and cadmium in cumin spice is 0.33 and 0.22 μg/g, respectively. Gaya and Ikechukwu (2016) studied that the concentration of heavy metal in Nigeria for ginger spice are (in mg/kg) 7.45±0.02, 3.42±0.01, 2.70±0.01 and 10.13±0.02 for cadmium, nickel, lead and zinc, respectively. Ozkutlu et al. (2006) reported that the concentration of cadmium is 0.07 mg/kg and that of zinc is 5.00 mg/kg in ginger spice. The permissible limit of nickel, zinc, lead and cadmium are 0.05, 0.1, and 0.1 mg/kg (WHO/FAO, 2011) and 0.2 mg/kg (Sharma, 2014), respectively.

For people in the areas covered in this research, ginger is common spice in food per day and a known medicinal remedy. As people directly consume ginger as spice and medicine, some heavy as well as trace elements that could cause health damage in the long run may be taken indirectly. Thus, study of heavy metals in ginger is of paramount importance. This research aimed to determine the concentration of heavy metals in ginger variety in some areas of Southern part of Ethiopia.

MATERIALS AND METHODS

Description of study area

This research was conducted in Kembatta Tembaro Zone in the Southern part of Ethiopia. This region is one of main ginger producing regions in Ethiopia. Three ginger producing woredas: Kachebira, Tambaro and Hadero were considered to collect samples. Figure 1 displays the administrative map of the study area.

Sample collection protocol

Fresh rhizomes of two ginger varieties namely hybrid (Bolbo) and Hargema samples were collected from ginger producing model farmers in the three selected woredas. Total of six samples were collected from three selected Woredas (two varieties from each woreda). Figure 2 presents ginger varieties considered in this work.

Sample preparation

The collected samples were washed thoroughly with tap water to remove absorbed particulates from the soil and then rinsed by de-ionized water. Its thin outer cover skin was removed with plastic knife and then chopped into pieces of approximately same size in order to facilitate drying uniformity. Samples were exposed to sunlight for two days to reduce moisture content. The samples were dried in the oven (carbolated fusion furnace) at a temperature of 105°C for 24 h to have dry mass basis (Wagesho and Chandravanshi, 2015). The dried samples were powdered in high speed universal disintegrator (Model F100) in a stainless steel mill till obtaining fine particles that pass through a 0.5 mm mesh and kept dry in a cleaned polyethylene bag.

Acid digestion method

A mass of 0.5 g of sieved powder of the samples was weighed out (Model ABS 220-4M) into acid washed glass beaker. Then the powder was digested with addition of 4 mL of HNO_3 (65%) and 2 mL of H_2O_2 (30%) in wet digestion system (Wagesho and Chandravanshi, 2015). After digestion, the solution was diluted with 10 mL de-ionized water. The same digestion procedure was followed for blank solution that was used for calibration curve determination (with minimum of correlation coefficient $R^2 = 0.9977$).

Experimental setup

Flame atomic absorption spectrophotometer (FAAS) (Model 210 VGP) was used to measure absorbance of each metal from which concentration of heavy metals was deduced. Hallow cathode lamps of specific wavelength were used as an exciting energy. Working conditions of experimental setup are shown in Table 1.

Statistical analysis

Data entry management and preliminary summaries were done on Microsoft Office Excel spread sheet. Means of data collected were determined. All analyses were carried out in triplicates and data presented as means. One-way analysis of variance (ANOVA) at $p < 0.05$ was used to determine statistically significant differences in the mean concentrations of metals among varieties as well as within a given variety in study areas. For comparison of the mean of the treatments, the Fisher's least significant difference (LSD) test were used to check the significance level. Data were further manipulated with ASA and SPSS 20.

RESULTS AND DISCUSSION

Concentrations of four heavy metallic elements (Zn, Ni, Cd, and Pb) in the digested samples of ginger were analyzed by FAAS. Results are shown in Table 2. Among the analyzed metals lead and cadmium were below the method detection limit. Mean concentrations of zinc range from 0.63 to 1.17 mg/kg while that of nickel are in the range of 0.15 to 0.21 mg/kg.

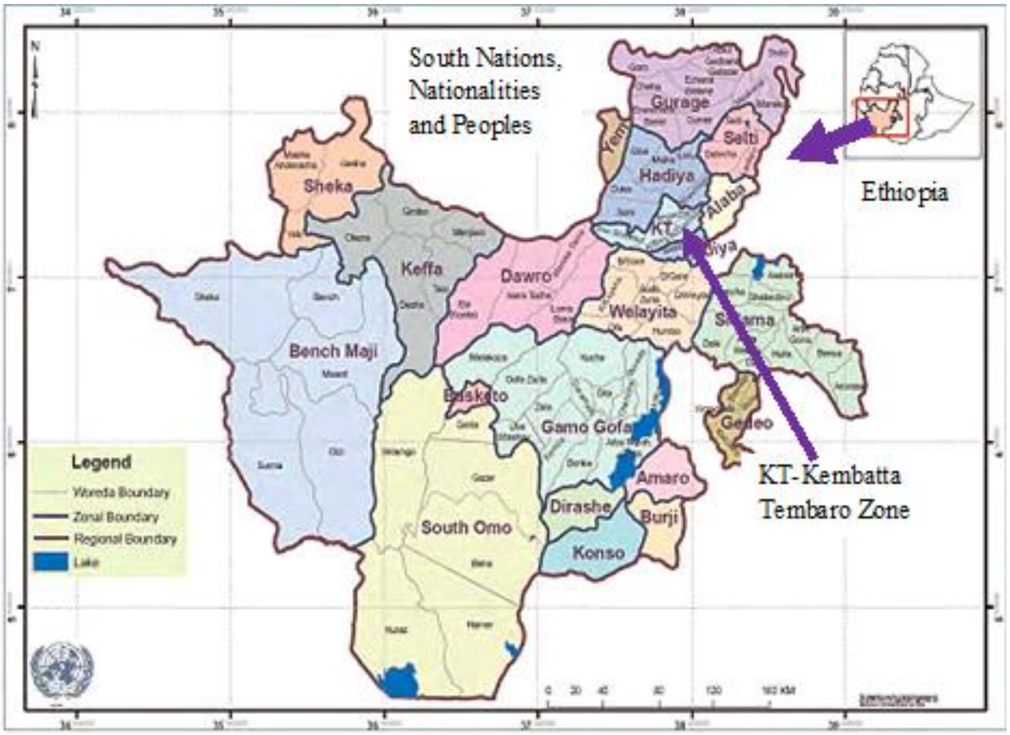

Figure 1. Map of study area as indicated by an arrow (retrieved at: www.rippleethiopia.org/page/snnpr).

Figure 2. Ginger varieties considered in this work (a) Hargema and (b) Bolbo (Hybrid).

Zinc (Zn)

Minimum and maximum zinc concentration of ginger in the studied area is 0.63 and 1.17 mg/kg, respectively. As shown from Table 2, varieties had differences in concentration in the three places considered in this work. One-way analysis of variance showed that the mean concentration of zinc of Hadero is statistically significantly different among other two sites, at $p < 0.05$. Variety wise, Fisher's combined probability test using the LSD criterion for significance determination indicated that the mean concentration of zinc is statistically significantly different from each other with $p < 0.05$ within the study area. As shown in Table 2, the variety Hargam possessed high zinc concentration as compared to Bolbo variety.

According to the study conducted in some parts of

Table 1. Working condition of the experimental setup.

Metal	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Energy (erg)	IDL (mg/l)	MDL (mg/g)	MQL (mg/g)	Recovery (%)
Cd	228.9	0.7	2.0	3.07	0.005	0.0002	0.0003	105
Ni	232	0.2	7.0	2.928	0.001	0.002	0.01	104
Pb	217	0.7	3.0	3.16	0.1	0.002	0.007	-
Zn	213.9	0.7	2.0	3.047	0.005	0.0006	0.002	93.2

IDL-Instrument detection limit, MDL-method detection limit, MQL-method quantification limit.

Table 2. Concentration of heavy metals in this work.

Study area	Variety	Heavy metal concentration (mg/kg)			
		Ni	Zn	Cd	Pb
Kachebira	Bolbo	0.20^{ba}	0.63^{c}	ND	ND
	Hargama	0.18^{bc}	0.95^{b}	ND	ND
Tambaro	Bolbo	0.17^{bc}	0.68^{c}	ND	ND
	Hargama	0.15^{c}	0.86^{b}	ND	ND
Hadero	Bolbo	0.21^{a}	0.87^{b}	ND	ND
	Hargama	0.18^{ba}	1.17^{a}	ND	ND
CV	-	8.79	8.61	-	-
LSD	-	0.029	0.132	-	-

Means with the same letter in a given column are not significantly different, ND-below method detection limit.

Ethiopia with dry weight digestion method, concentration of zinc in ginger is 38.5 to 55.2 mg/kg (Wagesho and Chandravanshi, 2015). Agrawal et al. (2011) reported that concentration of zinc is 0.46 to 2.74 mg/kg in India. Current result is in good agreement with results found in India but far less than that obtained in Ethiopia in previous study. Moreover, the present work has reported very low concentration of zinc as compared to Nkansah and Amoako, (2010) which is in Ghana (73 g/kg). Krejpcio et al. (2007) reported that the content of zinc concentration of spices in Polish markets is found to be 5.96 to 16.95 mg/kg which is higher than results obtained in this work. The mean concentration of zinc determined in this study is lower than the value determined in India (Devi et al., 2008) but greater than the value obtained (0.03-0.04 mg/kg) in Nigeria (Ajayi et al., 2013). The content of zinc in ginger sample of the current study (Ethiopia) is less than the permissible limit set by WHO/FAO (2011) in edible plants (50 mg/kg).

Nickel (Ni)

Minimum and maximum value of concentration obtained in this work for nickel is 0.15 and 0.21 mg/kg, respectively. Bolbo variety had relatively higher concentration of nickel than Hargama variety, but not statistically significant. Geographically, there is statistically significant difference in nickel concentration in Hadero, however, other two areas had statistically insignificant differences. In contrast to zinc, Bolbo variety possesses more nickel concentration than Hargama variety. However, the difference did not show statistical significance.

Nickel concentration of the present study is lower than the nickel content determined in Ethiopia in previously conducted research (5.46-8.40 mg/kg) (Wagesho Chandravanshi, 2015). The current work is also lower than nickel content obtained (43 g/kg) in Ghana (Nkansah and Amoako, 2010). Nickel content determined in the present study (Ethiopia) is higher than the permissible limit set by WHO/FAO (2011) in edible plants (1.63 mg/kg). However, nickel toxicity in human is not a very common occurrence because its absorption by the body is very low (Jabeen et al., 2010).

Lead (Pb) and cadmium (Cd)

In this experiment, both metals were below detection limits of the experimental technique employed. However, lead and cadmium were observed in some previous studies. Reports of Agrawal et al. (2011) showed that lead and cadmium concentrations in India were 0.5 to 12.60 mg/kg and 0.92 to 2.27 mg/kg, respectively. A research conducted on heavy metals in spices collected from Polish markets showed that the concentration of lead is 0.21 to 0.78 mg/kg and that of cadmium is 0.02 to 0.04 mg/kg. Moreover, it was determined to be 0.30 mg/kg for cadmium, in Nigeria (Oladoye and Jegede, 2016).

Conclusion

Flame atomic absorption spectroscopy was used to determine concentration of heavy metals (Ni, Zn, Pb and Cd) in ginger varieties with wet digestion method. Statistically significant difference of zinc concentration was observed within varieties as well as between values within the given study area. Nickel concentration showed a non-statistically significant difference among varieties but value from one study area (Hadero) showed statistically significant difference. Both zinc and nickel were found to be below WHO/FAO permissible limits and could not cause health problems. Lead and cadmium were not detected.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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