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Heavy metal contamination of Cabbage Sections from different farms in Ghana

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ABSTRACT

This study aimed at determining the levels of heavy metals; cadmium (Cd), mercury (Hg), arsenic (As) and lead (Pb) in whole cabbage and sections (outer, mid and inner) and soil samples from different farmlands (Obuasi and KNUST [Brunei and Agric]) using standard methods of digestion and atomic absorption spectroscopy (AAS). The level of Cd in the soil from Brunei was significantly higher (0.055 mg/kg ±0.002) compared to the samples from Agric (0.013 mg/kg ± 0.000) and Obuasi (0.015 mg/kg ± 0.0003). Soil sample from Obuasi had a significantly lower level of Pb (0.025mg/kg ± 0.024) compared to the samples from Brunei (0.039 mg/kg ± 0.0003) and Agric (0.034 ± 0.0003). In the whole cabbage, the levels of cadmium in the sample from Brunei (0.041mg/kg ± 0.004) was significantly higher ($p < 0.001$) compared to the samples obtained from Agric (0.023 mg/kg ± 0.003) and Obuasi (0.024 mg/kg ± 0.001). Cadmium levels were generally more concentrated in the inner and mid-sections of all samples obtained. The level of Pb and Hg were also generally higher in the mid and outer sections of the samples. It is concluded that the heavy metals were also more concentrated in the mid-sections while the inner section had relatively the least levels of these metals. It can be suggested that the inner whitish bulb of cabbage has least concentration of heavy metals analysed.

Key words: Cabbage, heavy metals, mercury, cadmium, arsenic, lead

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INTRODUCTION

Cabbage, *Brassica oleracea* is a plant belonging to the family Brassicaceae. It is a cool seasoned plant with a high tolerance for cold [1]. Cabbage has a thick stem, gray-green leaves and four petals in flowers. Cabbage leaves are red or green, smooth or wrinkled.They are low in carbohydrate, calories and fats; however they are good sources of protein which contains all the essential amino acids most especially the sulphur containing amino acids [2]. In Ghana, cabbage is mostly cultivated among the urban and peri-urban dwellers. Over the past years, there has been growing issues on the safety of consuming fresh vegetables such as cabbage as a result of their questionable safety due to their possible health risk associated with pesticide and fertilizer applications [3].

A heavy metal is a general collective term which is applicable to the group of metals and metalloids with an atomic density greater than 4 g/cm^3[4]. Heavy metals are grouped into the essential micronutrients (Fe, Mn, Zn, Cu, Ni, Mo) which are of importance to plants and the toxic heavy metals (Cd, Cr, Pb, Hg). Heavy metal contamination in the environment occurs mostly in areas where anthropogenic activities are high.Thus, the urban areas are most likely to experience metal poisoning [5]. Sources of such anthropogenic activities are mining and smelting of non-ferrous metals, addition of manures, sewage sludge, fertilizers and pesticides to soil, with a number of studies identifying the risks in relation to increased soil metal concentration and consequent crop uptake [6]. These heavy metals do not only pollute the surface water but also pollute the soil and ground water and subsequently enter into the plants, thus exposure to metals may be through diet or absorption into the skin [7].Heavy metals are present in food in minute quantities and they play important roles in the metabolism and life processes of man. These elements when taken in abnormal quantities or when the normal processes of elimination are impaired may lead to metal poisoning [8]. Permissible maximum levels for some heavy metals are; Cadmium – 0.05 mg/kg (for Brassica, bulb and fruiting vegetables), Lead – 0.1 – 0.3 mg/kg (for Brassica, bulb and fruiting vegetables), Mercury – 0.1 mg/kg (for salt and food grades) and Arsenic – 0.1 mg/kg (for vegetable oils) [9].

Soils contain both macro and microorganisms which are all necessary to support the growth of plant [10]. Plants take up metals by absorbing from the soil and also from parts of the plant that is exposed to air contaminated with heavy metals. It has been reported that more than average of heavy metal consumption (lead, cadmium, arsenic and mercury) is through food from plant origin. Urban soil contamination is mainly caused by anthropogenic activities such as traffic emission, industrial emission, and domestic emission, weathering of building and pavement surface and so on. However, in agricultural soil, the presence of heavy metals is due to smelting, waste disposal, vehicle exhaust, pesticides and use of fertilizers [7]. This study was aimed at determining the levels of heavy metals in cabbage (whole and sectioned) and the surrounding soil from the different farmlands with different environmental conditions.

MATERIALS AND METHODS

Sample collection: Samples were collected randomly from the three different farmlands; Obuasi (a mining community in Ghana), and two farming sites on KNUST campus (Agric farm using bore-hole water for irrigation and behind Brunei hostel using waste running water for irrigation). All the cabbages were collected at the consumption stage. The soil and the cabbages were collected and stored in polyethylene bags and were transported to the lab as soon as possible.

Sample preparation: The vegetables were thoroughly washed with running tap water to remove dust and other particles. For the analysis of whole samples, the cleaned plant samples were then sliced and dried in an oven at 60 ^{o}C for 2-3 days. They were then milled into fine powder for analysis. For the sectioned samples, the whole cabbage was cut into four pieces longitudinally and separated into three sections. The outer sections consisted of about 2.0 cm thickness of the outer greener layers. The mid sections consisted of about 2.0 cm thickness of the middle pale green layers, while the inner sections consisted of about 2.0 cm thickness of the inner whitish layers. These sections were treated separately as described above. The soil samples were dried for 2-3 days at room temperature and grounded using mortar and pestle and then sieved using a 2.00 mm sieve. All milled samples were stored in zip-locked polythene bags and stored in desiccators for analysis.

Sample analysis: All samples were wet digested. For cabbage samples (whole and sections), 1g of the powdered dried samples were weighedinto a crucible and ashed for 4 hours. Each ashed sample was transferred into a beaker and 10 ml of Aqua Regia (concentrated mixture of HCl or HNO_3) added. For each sample of soil, 10g was weighed into beaker and 10ml of DTPA solution added. The cabbage and soil mixtures were centrifuged at 3000 rpm for 10 minutes. The samples were then decanted and stored in glass vials for analysis. The digests were then analysed for thelevels of heavy metals by using Atomic Absorption Spectroscopy (AAS).

Data analysis: Each determination was made in triplicate and the levels of heavy metal expressed in mg/kg of sample. Data was analysed using GraphPad Prism 5 for Windows. Data was expressed as mean ± SEM and analysed by ANOVA followed by the Newman – Keuls multiple comparison test. Values for which $p<0.05$ was considered as statistically significant.

RESULTS

The figures below show the different levels of heavy metals (cadmium, lead, arsenic and mercury) in the cabbages (whole and section) and soil samples obtained from the different farmlands (KNUST[Brunei and Agric] and Obuasi).

Figure 1 shows the levels of heavy metals in the whole samples; cadmium (0.022-0.046 mg/kg), arsenic(0.038-0.041 mg/kg), lead (0.014-0.027 mg/kg) and mercury (0.038-0.044 mg/kg). Cadmium levels were significantly higher ($p<0.001$) in Brunei samples compared to the other samples. Figure 2 shows levels of heavy metals in the different sections of the cabbage (inner, mid and outer).Arsenic levels were about 0.04 mg/kg in all sections except a significantly higher level ($p<0.001$) in the mid-section of Obuasi samples. Cadmium levels were found to be concentrated more in the mid-section of Obuasi samples ($p<0.01$ against inner and $p<0.001$ against outer) but more in the outer-section of Brunei samples ($p<0.01$ against mid and $p<0.05$ against inner). Its levels were higher in inner-sections of Agric samples though not significant. Lead levels were also observed to be more concentrated in the mid and outer-sections of Agric samples ($p<0.001$ against inner) and Obuasi samples ($p<0.001$ for mid and outer) respectively.

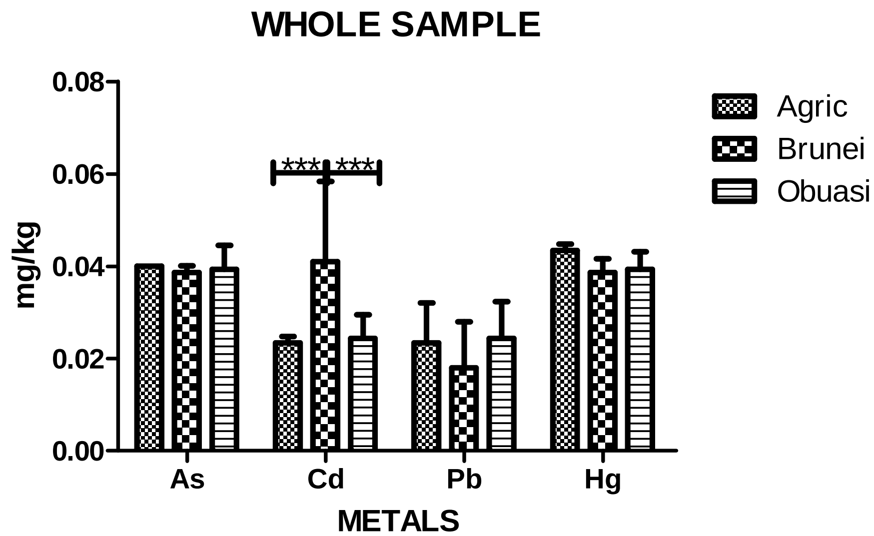
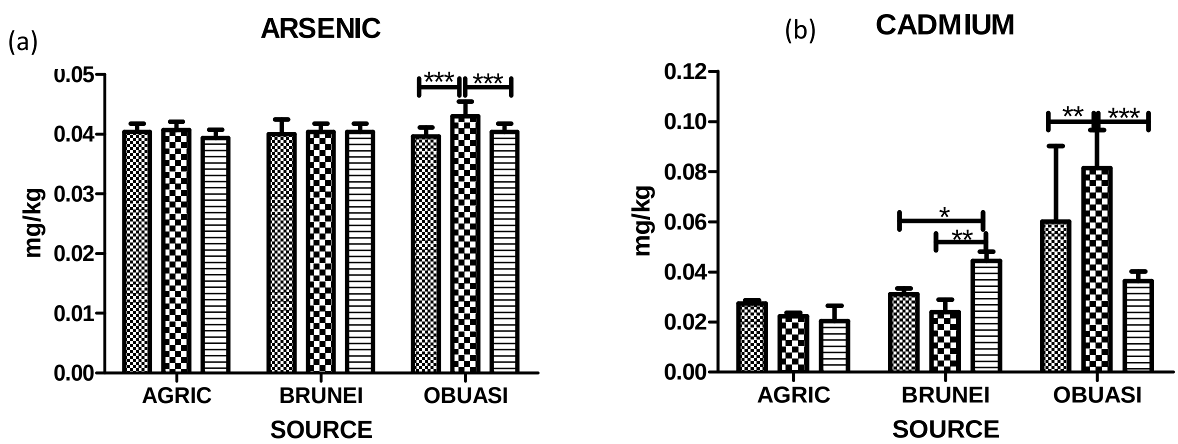


Fig.1: Levels of heavy metals in whole samples of cabbage obtained from Agric, Brunei and Obuasi farmlands.
*Each bar represent a mean ±SEM. *** p<0.001*

Figure 3 shows the heavy metal content of soil samples from the various farmlands. Cadmium and lead levels were significantly ($p<0.001$) higher in Brunei soil.



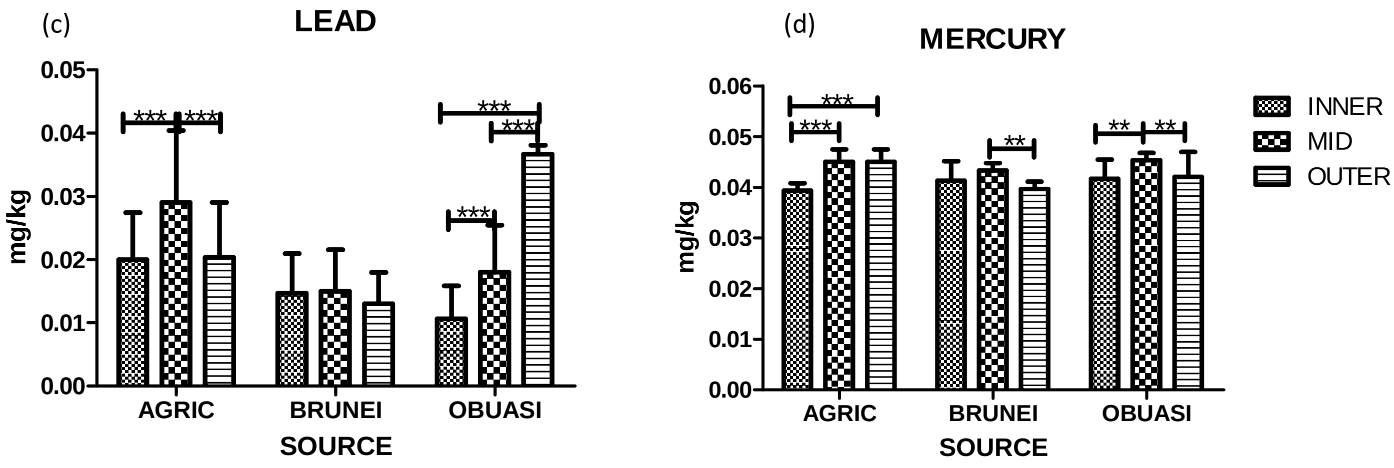


Fig.2: Levels of As, Cd, Pb and Hg in the different sections (inner, mid, outer) of cabbage obtained from Agric, Brunei and Obuasi farmlands. *Each bar represent a mean ±SEM. ** p<0.01; *** p<0.001*

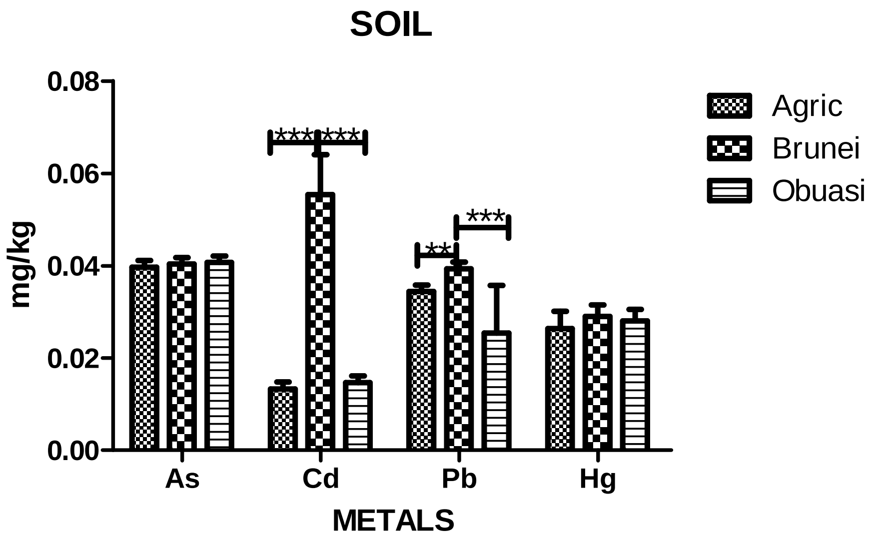


Fig.3: Levels of heavy metals in soil samples obtained from Agric, Brunei and Obuasi farmlands.
*Each bar represent a mean ±SEM. *** p<0.001*

DISCUSSION

From Figure 1 above, it was observed that all the whole samples from the different farmlands contained relatively the same amount or levels of lead, arsenic and mercury with no significant differences observed when they were compared. However, the level of Cd in the samples from Brunei (0.041 ± 0.00) was significantly higher (p<0.001) compared to those from Agric (0.023 ± 0.0003) and Obuasi (0.024 ± 0.001).This increase in Cadmium in the Brunei samples could be due to the source of irrigation (waste water) used on the farmlands and also the type of fertilizers used in the cultivation of the crop. The high Cd levels in the soil from the Brunei samples could also lead to subsequent accumulation in the cabbage since Cd has a high capacity for transferring from soil into vegetables[11].Also, it was observed that the mean levels of Pb and Hg were within the ranges set by the Codex.

Comparatively, work done by Jafarian-Dehkordi and Alehashem [12] showed that in most vegetable samples collected from the suburban of Isfahan city, Iran , the levels of Cd (0.00 to 6.00 µg/g) were significantly higher than the acceptable levels set by the WHO/FAO. This is consistent with the findings in this study for the mean levels of Cd in the Cabbage samples. Interestingly, results obtained by Jafarian-Dehkordi andAlehashem [12], also showed that the levels of Pb (0.00 to 7.14 µg/g) in the vegetable samples were also higher than the acceptable levels. This inconsistency could be due to the fact that,the main source of water for the irrigation of the farms in this region is Zayandeh-Rood river whichcrosses Isfahan city with several industries located at its the periphery.Work done by Chang *et al*. [11] showed that soil samples from farmlands in the Pearl River Delta region, South China contained 0.29 ± 0.26mg/kg of Hg, 0.17 ± 0.13mg/kg of Cd, 42.5 ± 25.6mg/kg of Pb and 20.0 ± 20.8mg/kg of As.

For the samples that were sectioned (Figure 2a) it was observedthat the levels of As in all the sectioned parts of samples from Agric and Brunei was not statistically different though it was higher than the PTWI standards set by the WHO for arsenic. However, the samples from Obuasi contained relatively the highest levels of cadmium in its mid-section with significant differences when compared with the inner and outer sections. This increase of arsenic in the Obuasi samples may be due to the fact that arsenic's main source is from manmade activities, majorly mining. Thus, Obuasi being a mining area may be heavily polluted with arsenic in the environment and consequently polluting the cabbage.

From Figure 2(b), it was observed that the levels of Cd in all sections the samples were higher than PTWI standards set by WHO for cadmium. However, the samples obtained from the Agric farmlands contained relatively the lowest levels of cadmium with no significant difference between the sections. This low level of cadmium in the Agric samples may be because the Agric farms use potable water for irrigation and also because organic fertilizers were used for the cultivation with the less likelihood of it being contaminated with cadmium from refuse and chemical fertilizers. For the samples obtained from the Brunei farmlands, the outer sections contained high levels of Cadmium (0.044 ± 0.001) with significant difference ($p<0.05$ and $p<0.01$ respectively) when compared with the inner- and mid-section. The Obuasi samples were observed to contain the highest levels of Cadmium with most of it accumulating in the mid-section (0.081 ± 0.0035). This high level could be attributed to the fact that, mining activities in the area turns to increase Cadmium pollution in the environment and hence subsequent accumulation in the vegetables in the farmland.

From Figure 2c, it was observed that all the samples contained levels of lead that were below the standard set by the Codex (2013)[9]. However, samples obtained from the Brunei farmlands contained the relatively the lowest levels of lead, with no significant differences observed when the sections were compared. The samples obtained from the Obuasi farmlands contained highest levels of Pb amongst all the samples with most of it concentrated in the outer sections, this may be due to the mining activities in Obuasi since lead is known to be high in the mining areas. For the Agric samples, it was noticed that the samples contained relatively higher levels of lead in its midsection, this could be because the Agric farm is very close to the main street where vehicles ply almost constantly, thus, vehicles using leaded petrol may have emitted lead into the environment which may have polluted the environment and consequently the crops grown on the farm.

From Figure 2d, all the samples from the different farmlands contained relatively the same levels of mercury with the mid-sections containing the highest levels with significant differences when compared to the other sections. The levels were lower than the PTWI standard set by the WHO for mercury in foods. This similarity in all the samples where they contained relatively the same amount of mercury may be accounted for by the fact that, mercury is produced mainly by anthropogenicactivities such as mining, emissions of gases, dumping of refuse and the like, and these activities are characteristic to urban areas. Therefore since all the farmlands are located in the urban areas there is the likelihood of the crops being contaminated with mercury.

For the soil samples, it was observed that all the soil samples obtained from the different farmlands contained relatively the same levels of As and Hg with no significant differences observed amongst them. However, for the cadmium metal, it was observed that Brunei contained the highest level of cadmium with significant differences observed when compared with the Agric and Brunei soil samples. Also, for lead, Brunei contained significant highest levels when compared with the soil obtained from Agric and Obuasi. The Agric soil was also significantly higher in Pb concentration than the soil obtained from Obuasi. The presence of these heavy metals in the soil from the farmlands may be due to anthropogenic activities. These heavy metals present in the soil may also be due to waste water which were used on most of the farmlands leading to the deterioration of the health of the soil and thus contaminating the vegetables as they absorb these heavy metals.

CONCLUSION

It can be concluded from the above results that the mid sections were observed to contain relatively most of the metals, whilst the inner sections contained relatively the least levels of metals. It can also be concluded that mercury, lead and cadmium were accumulated mostly in the mid and outer sections of the cabbages whilst arsenic was accumulated mostly in the mid sections. These findings indicate that the cabbage plant, a leafy vegetable, stores the metals mostly in the mid-section and outer section. It is thus suggested that the inner whiter section of the cabbage is safer for consumption.

Recommendation

Further work should be done to determine the heavy metals present in the irrigation water to ascertain the sources of metals in the cabbages. Also, similar assessment could be done on other vegetables to determine the levels of these heavy metals in their sections.

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