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DETERMINATION OF ESSENTIAL AND TOXIC METALS IN MEATS, MEAT PRODUCTS AND EGGS BY SPECTROPHOTOMETRIC METHOD

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Abstract

The concentration of essential metals such as Fe, Cu, Mg, Co and Zn and toxic metals such as Pb, Cd, Cr, As and Ni were determined in a number of animal meats, organ meats, meat products, and eggs by using UV-visible and atomic absorption spectrophotometry (AAS). The essential metal estimation in the investigated samples indicated the following range of concentration: Fe: 11 - 623 mg kg^{-1}, Cu: 1 - 165 mg kg^{-1}, Mg: 16 - 1372 mg kg^{-1}, Co: 0.01 - 48 mg kg^{-1}, Zn: 15 - 295 mg kg^{-1}. These concentrations of essential metals are in the range of human necessities. The concentrations of toxic metals in the same samples were: Pb: 0.03 - 43 mg kg^{-1}, Cd: 0.01- 8 mg kg^{-1}, Cr: 0.02 - 5 mg kg^{-1}, As: 0.004 - 3 mg kg^{-1} and Ni: 0.03 - 41 mg kg^{-1}. The concentration of arsenic in all samples was found negligible and this indicates that the investigated samples are safe from arsenic toxicity. The concentrations of other four toxic metals being very negligible in most of the samples indicate that these foodstuffs are reasonably safe from metal toxicity. However a few samples which exhibited higher concentrations of these metals above their tolerance limits are alarming for the public health and demand regular examination of these items before coming to the markets. The information obtained from the present investigation is expected to be useful to the general people of this region in selecting meats as their diets.

Keywords: Meats, Organ meats, meat products, eggs, AAS, Heavy metals concentrations.

Introduction

Metals are found in all living organisms where they play a variety of roles. Metals such as Fe, Cu, Mg, Co, Zn are essential for human body but chronic metabolic disturbances may occur due to the deficiency or excess of these metals [1]. It is important to keep the level of these metals in their proper ranges for maintaining proper metabolic functions in human body. It can be done by taking selected foods in daily diets from a list which can give information about the metal contents of different foods [2]. Non essential elements such as Pb, Cd, Cr, Ni and As are considered to be toxic and their presence in the body can cause profound biochemical and neurological changes in the body [3].

The sources of toxic metals in the environment are the fossil fuels, mining industries, waste disposals and municipal sewage. Farming and forestry also contribute to the metal

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content in the environment due to the uses of fertilizer, pesticide and herbicides. As a consequence of environmental pollution, the contaminants may enter the food chain. We are taking food for living. So the major route of entry of most metals into the body is through the diet. Animal meats, meat products and eggs are consumed largely by the general people of Bangladesh since they contain proteins, amino acids, minerals and vitamins. It is very essential to know the toxic metal contents in the foodstuffs we are consuming everyday. The objective of this work is to estimate the levels of toxic metals such as Pb, Cd, As, Cr and Ni as well as essential metals such as Fe, Cu, Mg, Co and Zn in these foods.

Experimental

Sample preparation

Animal meats (local cow, Indian cow, buffalo, goat, local hen and farm hen), organ meats (tongue, lung, liver, spleen, and heart of cow and buffalo) were collected randomly from six different market of Chittagong city area. In the same manner the same samples were also collected from Comilla city area. Meat products (chicken burger, chicken samucha, anthon, chicken patties, chicken sandwich, beef pizza, hot dog, beef roll, chicken roll, and chicken wing) were collected randomly from six different first food shop of Chittagong city area. Meat products are usually retailed; so their origin could be varying diversified in the different shops. Egg samples (egg of local hen, farm hen and duck) were collected from Chittagong city area. Yolk and white portion of an egg analyzed separately.

The solutions of these samples were prepared by wet digestion method. Clean and dried solid flash samples of meat and organ meat, meat product (as it collected freshly) and boiled samples of egg were taken in a three neck round bottom flask and added 50 mL of RD H_2O with the sample. These were boiled for about four hours and then evaporated the solvent. At room temperature 100 mL of HNO_3 and $HClO_4$ mixture (5:1: v/v) were added with the boiled sample. This was refluxed at 120-125^0 C (20 hours) until a clear solution appeared. The volume of the solution has been reduced to about 3-5 mL by condensation. At room temperature added few mL of RD H_2O and filtered through Whatman-40 filter paper into a 100 mL volumetric flask and made up to the mark with RDH_2O. All the samples solution under the present investigation were prepared in similar manner and stored at room temperature for Spectroscopic measurement. A blank solution was also prepared for each group of sample by using all reagents except the sample.

Analytical Techniques

The amounts of Fe, Cu and Mg in animal meats under the present investigation were determined by UV-visible double beam spectrophotometer, model Cintra, Australia. For determining the amounts of Fe, Cu, Mg, Co, Zn, Pb, Cd, Cr and Ni in rest of the samples, an atomic absorption flame emission spectrophotometer, model AAS-240FS Varian Australia was used. The concentration of As in all samples was determined by hydride vapor generation of Atomic absorption graphite emission spectrophotometer, model AA-

6401F, Shimadzu, Japan. The analysis was carried out using respective hollow cathode lamps under standard instrumental conditions (Table: 2). All the spectroscopic measurements of the standard metal solutions as well as the sample solutions were done at their respective wavelength of maximum absorptions λ_{max}. The accuracy of the instrumental methods and analytical procedures were checked by duplications of the samples, as well as by using the independent reference standard solutions (Table 3). Moreover, the known concentration of an independent respective metal solution is measured periodically with the measurement of sample solution. When the measured value of the standard metal solution had shown deviation more then ten percent from its known concentration then recalibration had done for the respective metal. Thus the accuracy and precession of the analytical data were strictly followed throughout the present study. The detection limit of the element for the instrument and the spike recovery rates of the elements analyzed under the experimental conditions were determined (Table 4).

Reagents and Solutions

The chemicals and reagents used for the analysis were of the AR grade and redistilled water (RD H_2O) was used in preparation and dilution of all the solutions. $HClO_4$ and HNO_3 were procured from E. Merk, Germany. The necessary standard metal solutions were prepared in ppm level for constructing a calibration curves of Mg, Fe and Cu by UV-Visible spectrophotometer (Table: 1). 1000 ppm spectral solutions of Fe, Cu, Mg, Co, Zn, Pb, Cd, Cr, As and Ni for AAS were obtained from BDH, England, for calibration purpose. All working solutions were prepared by de-ionized water. The respective metal concentrations were determined from each of the corresponding calibration curves.

Results and Discussion

It appears that there was a high content of Fe (11.36 - 623.12 mg kg^{-1}) in all foodstuffs. The highest level of Cu was found in meat products (Table: 7) and the lowest value was found in eggs (Table: 8). Rest of the samples contain adequate level of Cu. Although Cu is essential element in trace amount but can be toxic when it exceeds the maximum permissible limit. Copper is responsible for hyperactivity in autistic children. The concentration of Co was found in the ranged 0.01-5.13 mg kg^{-1} but only beef roll of meat products contained 48.3 mg kg^{-1}. The concentration of Zn was found to be 14.89 to 295.36 mg kg^{-1}. Zinc was found excessively in most food items. Zinc is an essential trace element for animals, being involved in protein synthesis and as a constituent of many metalloenzymes[4]. The concentration of Mg in most of the samples was found higher than the other essential metals. This indicates that all the investigated samples are very good sources of Mg. The recommended daily allowance (RDA) of Fe, Cu, Mg, Co and Zn are 10-15, 1.5-3.2, 300-500, 1-1.5 and 12-15 mg per day respectively for an adult person. The study revealed that the concentration of the metals in the foodstuffs are in the range of

human necessities on the basis of their recommended daily allowance and the people should not worry about them except in the case where their deficiency produces diseases [2].

Table 1. Operating parameters of AAS used in the analysis of trace metals

Condition	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
Wavelength (nm)	248.3	324.8	285.2	240.7	213.9	217	228.8	193.3	357.9	232
Slit (nm)	0.5	0.5	0.5	0.2	1.0	1.0	0.5	0.5	0.2	0.2
Lamp Current (m A)	4	4	4	7	5	10	4	10	7	4
Air flow (L/m)	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Acetylene flow (L/m)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.0	2.0

Table 2. Accuracy of the analytical data with reference to the NIST standard

Name of the metal	Fe	Cu	Mg	Co	Zn	Pb	Cd	Cr	Ni
Certified Value (ppm)	1	0.2	0.1	0.5	0.2	0.5	0.2	0.5	0.5
Measured Value (ppm)	0.974 ±(0.007	0.196 0.003	0.104 0.003	0.496 0.004	0.196 0.001	0.534 0.01	0.197 0.002	0.504 0.017	0.491 0.008)*
Deviation (%)	2.6	2	4	0.8	2	6.8	1.5	0.8	1.8

*Measured values are mean ±SD of seven replicate analyses

Table 3. Detection limit (DL) and Spikes recovery of the metals

Metals	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
DL(ppm)	0.01	0.01	0.01	0.01	0.003	0.03	0.002	0.0003	0.05	0.02
Recovery (%)	92-97	90-99	93-103	93-102	93-97	93-100	95-103	95-101	90-97	96-102

Table 4. Standard compounds used for the λ_{max} and calibration curves (UV-visible Spectroscopy)

Element	Standard Compounds	Reference / λ_{max}	Measured / λ_{max}	Slit Width / nm
Fe	$FeNH_4(SO4)_2$	510	509.23	1.5
Cu	$CuSO_4.5H_2O$	435	435.62	1.5
Mg	$MgSO_4.7H_2O$	520	527.25	1.5

Table 5. Amounts (mg kg^{-1}) of essential and toxic metals in animal meats

Location	Meat of animal	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
Chittagong	Cow (Local)	198.55	11.51	483.23	4.0	200.20	24.9	8.04	0.18	1.22	2.64
		±(7.56	1.35	10.93	0.06	0.08	0.04	0.002		0.02	0.007)
	Cow (Indian)	49.53	2.13	212.74	1.0	43.09	2.05	1.57	0.14	2.55	BDL
		±(2.12	0.72	7.52	0.01	0.02	0.01	0.003		0.004)	
	Buffalo(Local)	176.35	6.01	522.30	1.43	135.15	3.06	0.57	0.16	5.36	0.13
		±(8.41	0.52	3.23	0.05	0.06	0.12	0.04		0.01	0.003)
	Goat (Local)	33.43	3.92	281.47	1.28	82.33	1.35	0.15	0.33	0.08	0.35
		±(3.13	1.62	3.51	0.04	0.05	0.004	0.006		0.003	0.001
	Cock (Local)	60.27	10.33	649.68	2.30	168.7	41.94	5.20	0.08	0.69	1.13
		±(5.33	1.45	17.32	0.02	0.07	0.003	0.002		0.001	0.04)
	Cock (Farm)	22.46	3.15	281.86	2.65	22.77	0.81	0.11	0.06	BDL	0.72
		±(4.53	1.21	10.53	0.03	0.01	0.003	0.001			0.002)
Comilla	Cow (Local)	131.69	1.88	390.13	2.87	152.88	0.29	0.01	0.04	BDL	3.4
		±(11.54	0.55	13.25	0.52	0.004	0.005				0.24)
	Cow (Indian)	53.11	31.78	260.72	0.04	77.08	43.37	0.41	0.02	0.02	41.4
		±(6.21	5.21	11.21	0.001	0.002	0.01	0.001			0.01
	Buffalo (Local)	143.87	4.47	472.18	0.23	76.92	0.64	BDL	0.49	BDL	4.94
		±(5.46	0.52	4.23	0.08	0.003	0.08				0.31)
	Goat (Local)	27.17	5.90	238.62	BDL	58.28	1.36	0.05	BDL	0.37	BDL
		±(2.21	1.23	5.57	0.002	0.001	0.0002)				
	Cock (Local)	16.65	1.27	426.96	0.22	111.20	0.08	0.01	BDL	BDL	BDL
		±(3.45	1.02	18.23	0.04	0.06	0.02)				
	Cock (Farm)	23.85	1.82	401.86	0.84	14.89	0.03	BDL	0.01	BDL	0.03
		±(5.24	0.63	20.21	0.001	0.003	0.0002				0.0002)

± indicates SD of three replicate measurements

Table 6. Amounts (mg kg^{-1}) of essential and toxic metals in the organ meats of cow and buffalo of Chittagong City area

Animal	Organ	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
Cow	Tongue	36.75	0.17	105.13	1.60	41.11	0.75	BDL	0.01	0.06	BDL
		±(0.02	0.03	0.05	0.002	0.001	0.001			0.002)	
	Heart	33.54	0.54	81.62	5.13	263.64	0.67	0.06	0.03	0.86	1.15
		±(0.03	0.03	0.002	0.004	0.01	0.003	0.002		0.005	0.003)
	Lung	99.31	BDL	82.78	0.01	22.47	16.3	1.12	0.15	0.10	BDL
		±(0.01		0.01	0.002	0.004	0.01	0.002		0.003)	
	Liver	99.29	0.81	59.65	1.05	20.09	0.72	0.03	0.01	BDL	BDL
		±(0.02	0.001	0.004	0.003	0.004	0.002	0.0001)			
	Spleen	123.3	0.15	49.61	3.28	29.24	5.5	0.35	0.11	0.08	0.43
		±(0.85	0.05	1.05	0.23	1.21	1.03	0.04		0.03	0.25)
Buffalo	Tongue	43.16	1.71	81.17	1.24	288.46	7.47	0.75	0.08	0.71	BDL
		±(0.003	0.003	0.002	0.001	0.002	0.004	0.005		0.002)	
	Heart	56.95	0.25	100.5	3.28	25.76	0.51	0.25	BDL	BDL	BDL
		±(0.03	0.002	0.004	0.001	0.004	0.002	0.001			
	Lung	48.98	1.68	32.91	1.75	295.36	4.7	0.44	0.07	0.44	0.05
		±(0.04	0.005	0.01	0.003	0.006	0.001	0.005		0.003	0.002)
	Liver	85.2	2.44	16.11	2.84	160.76	0.98	0.15	BDL	0.93	0.64
		± (0.02	0.001	0.006	0.003	0.004	0.002	0.001		0.001	0.002)
	Spleen	100.6	0.20	75.75	2.72	44.81	4.53	0.25	BDL	1.57	0.17
		±(2.35	0.02	4.03	0.41	2.34	1.24	0.03		0.6	0.03)

Table 7. Amounts (mg kg^{-1}) of essential and toxic metals in meat products (first foods) of Chittagong city area

Meat products	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
Chicken Burger	11.36	0.91	27.88	0 .10	17.20	BDL	0.006	0.01	4.15	BDL
	±(0.004	0.002	0.003	0.001	0.004	0.001	0.005		0.002)	
Chicken Samucha	219.44	7.07	280.51	1.05	34.04	1.46	0.003	0.004	3.76	1.75
	±(0.003	0.005	0.003	0.001	0.002	0.007	0.002		0.002	0.003)
Anthon	599.84	108.56	454.98	1.18	284.65	BDL	0.14	0.008	3.91	4.85
	±(0.001	0.003	0.003	0.001	0.002	0.005	0.005		0.002	0.004)
Chicken Patties	294.02	16.90	355.41	0.03	35.76	BDL	0.23	0.008	4.33	3.72
	±(0.007	0.002	0.004	0.001	0.002		0.004		0.005	0.002)
Chicken Sandwich	171.14	0.75	332.52	2.03	18.36	BDL	0.20	BDL	3.23	BDL
	±(0.004	0.003	0.006	0.001	0.003		0.004		0.002)	
Beef Pizza	230.27	8.27	341.51	0.03	37.85	2.45	0.006	BDL	2.89	BDL
	±(0.005	0.005	0.004	0.005	0.008	0.004	0.005		0.007)	
Hot Dog	172.41	110.90	344.02	0.01	65.55	1.01	0.009	BDL	3.05	0.49
	±(0.003	0.006	0.002	0.001	0.002	0.008	0.005		0.002	0.001)
Beef Roll	93.47	165.02	341.77	48.3	112.67	4.62	0.003	2.73	BDL	2.73
	±(0.007	0.008	0.002	0.001	0.003	0.004	0.005			0.008)
Chicken Roll	290.09	97.28	332.59	0.11	62.03	BDL	0.016	BDL	BDL	0.23
	±(0.003	0.006	0.002	0.001	0.002	0.008	0.005			0.003)
Chicken Wing	623.12	153.80	1372.54	0.04	138.38	3.94	0.021	BDL	BDL	2.68
	±(0.009	0.001	0.002	0.001	0.002	0.005	0.008			0.002)

Table 8: Amounts (mg kg^{-1}) of essential and toxic metals in eggs of Chittagong city area

Name of Egg	Portion	Fe	Cu	Mg	Co	Zn	Pb	Cd	As	Cr	Ni
Hen (local)	White	9.48	0.22	73.59	BDL	1.41	0.3	0.05	BDL	BDL	BDL
		±(0.005	0.003	0.003		0.001	0.002	0.004)			
	Yolk	115.1	0.42	147.7	0.77	102.73	11.8	0.99	BDL	BDL	4.26
		±(0.003	0.003	0.002	0.001	0.002	0.004	0.005			0.002)
Total		124.58	0.64	221.29	0.77	104.14	12.1	1.04	BDL	BDL	4.26
Hen (farm)	White	2.96	0.1	43.26	BDL	16.88	1.06	BDL	BDL	BDL	12.81
		±(0.008	0.005	0.002	0.001	0.002	0.004	0.005			0.007)
	Yolk	27.27	0.16	75.96	1.6	81.97	BDL	0.08	BDL	BDL	2.79
		±(0.003	0.003	0.0025	0.001	0.002	0.005	0.005			0.004)
Total		30.66	0.26	119.22	1.6	98.85	1.06	0.08	BDL	BDL	15.6
Duck (local)	White	32.97	0.17	496.5	BDL	0.61	0.32	BDL	BDL	BDL	BDL
		±(0.003	0.003	0.002	0.001	0.008	0.004	0.005)			
	Yolk	11.03	0.24	134.3	4.67	72.18	0.02	0.064	BDL	0.02	0.59
		±(0.007	0.003	0.002	0.001	0.002	0.004	0.003			0.006)
Total		44 .0	0.41	630.8	4.67	72.79	0.34	0.064	BDL	0.02	0.59

The highest concentration of Pb was found in animal meat of local cow and local hen of Chittagong that are 24.9 and 41.94 mg kg^{-1} respectively, whereas the highest concentration of Pb was found in animal meat of Indian cow and local goat of Comilla that are 43.37 and 1.36 mg kg^{-1} respectively (Table: 5). The organ meat of cow and buffalo of Chittagong contain the Pb in the ranges of 0.67 to 16.3 mg kg^{-1} and 0.51 to 7.47 mg kg^{-1} respectively (Table: 6). Beef roll, chicken wing, and beef pizza contain higher amount of Pb among the meat products, their values are 4.62, 3.94 and 2.45 mg kg^{-1} respectively (Table:7). The amount of Pb in egg is very negligible except the egg of

local hen (12.1 mg kg^{-1}) (Table: 8). The recommended daily allowance of Pb is 0.3 mg per day [5] and the maximum permissible limit (MPL) of Pb in food stuff is 1-5 mg kg^{-1} [6]. It was revealed from the study that few of the meat samples (Table: 5) contain significantly higher amount of Pb than those studied in USA, Canada, Slovenia, Spain and Palestine [7-11]. But meat products, eggs and most of the meats are safe to human health considering the RDA and MPL value of Pb. Pb is stored mainly in the liver and kidney. Lead toxicity affects directly the activities of different enzymes working in the body [12]. The concentration of Cd in animal meat of Chittagong and Comilla city are in the ranges 0.11-8.05 mg kg^{-1} and 0.01 to 0.41 mg kg^{-1} respectively (Table: 5). The amount of the metal in organ meat of cow and buffalo are in the ranges 0.03-1.12 and 0.15-0.75 mg kg^{-1} respectively (Table: 6). The RDA of Cd is 0.2 mg per day and the MPL for cadmium in muscle of livestock and poultry is 0.2 mg kg^{-1} [13,14]. The concentration of Cd in meat products and in eggs is within the RDA and MPL value. Cd content in some meats (Table: 5) is significantly higher and these are not safe to human health. When the concentration of Cd in diet is higher than RDA and MPL value, it accumulates especially in the kidney and the liver that can cause serious biological and neurological changes in human body even at ultratrace level[3]. The concentration of As in the studied samples were found below the RDA limits, even the amount in most of samples was below the detection limit that indicates these foodstuffs are not harmful for human health in terms of arsenic toxicity.

The concentration of Cr in animal meat, organ meat and meat products are in the ranges 0.02-5.36 mg kg^{-1}, 0.06-1.57 mg kg^{-1} and 2.89-4.33 mg kg^{-1} respectively and the amounts are within the permissible limit in eggs(Table: 5-7). The investigation shows that the concentration of Cr in the meat products and a very limited number of meats of Chittagong city is significantly higher than those studied in abroad. Chromium, particularly Cr (III) plays an important role in the body function (metabolic functions, cofactor of insulin etc.) in trace amount but it turns to be toxic when it exceeds the tolerance limit. Cr (VI) is toxic and has no beneficial role in human body [12]. The highest amount of Nickel was found in animal meats of local cow (2.64 mg kg^{-1}) of Chittagong city followed by local hen (1.13 mg kg^{-1}) (Table: 5). The egg of firm hen shows the highest amount of Ni (15.6 mg kg^{-1}) followed by egg of local hen (4.26 mg kg^{-1}) (Table: 8). Anthon, chicken patties, beef roll, chicken wing of meat products contain 4.85, 3.72, 2.73, 2.68 mg kg^{-1} of Ni respectively (Table: 7). The presence of Ni in rest of the samples is negligible compared to the RDA value of Ni and are safe from the Ni toxicity. The study reveals that few of the foods contain higher amount of Ni. Appropriate amount of Ni in human body plays roles in regulating of prolactine and stabilization of RNA and DNA structures [12]. Excessive intake of Ni produces severe allergic reaction, bronchial asthma, dermatitis, aczema and myocardial infection [15].

Conclusion

The study reveals that meats, meat products and eggs are the good sources of macro and micro nutrients and also most of the studied foodstuffs contain the toxic elements within consumable limits. Another important point is that all the studied food items are safe

from arsenic toxicities. But some of the food items bear noticeable amount of toxic metals such as Pb, Cd, Cr and Ni. The present study suggests avoiding those foods as much as possible. Moreover, concerned authority should take necessary steps for reducing the toxic metal contamination into the food chain. This study also provided baseline data on toxic metal concentrations for meats, meat products and eggs in this region of Bangladesh.

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