Heavy Metals and Formaldehyde Levels in Turkey and Chicken Meat Sampled in Selected Cities in Nigeria

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Abstract

Safety of poultry meat for human consumption is a critical issue with respect to contamination of food chain with chemicals, heavy metal and microbes. This work was aimed at quantifying the concentration of formaldehyde and heavy metal levels in poultry products obtained in Lagos, Abuja, Port-Harcourt and Ibadan. The levels of heavy metals in the imported turkey wings ranged from 0.0023 to 0.0246 mg/kg lead; 0.0008 to 0.0100 mg/kg cadmium; 0.0128 to 0.0389 mg/kg chromium and 0.0001 to 0.0004 mg/kg mercury, while the levels of heavy metals in the imported chicken legs (thigh + drumstick) ranged from 0.0061 to 0.0238 mg/kg lead; 0.0008 to 0.0103 mg/kg cadmium; 0.0188 to 0.0413 mg/kg chromium and 0.0001 to 0.0020 mg/kg mercury across the four cities. The heavy metals were highest in chickens obtained from Lagos and least in Ibadan, with mercury and chromium having the overall least and highest heavy metal concentration, respectively. The heavy metals in the imported chicken was higher than in the local counterpart; 0.0004 mg/kg Lead, 0.0 mg/kg Cadmium, 0.0024 mg/kg Chromium and 0.0 mg/kg (undetectable) Mercury. Hence, the concentrations of heavy metals in the poultry parts obtained from Port-Harcourt, Lagos, Abuja and Ibadan were within the permissible limit. Formaldehyde concentration in the imported turkey was within the permissible range of 154.28 to 196.56 mg/kg and for the imported chicken 151.45 to 196.56 mg/kg. Formaldehyde was however not detected in the locally produced commercial chickens.

Keywords: Food chain, Food safety, Formalin, Heavy metals, Poultry.

Introduction

Meat is quite an indispensable component of most staples in the diets of Nigerians. This is owing to its essence in meeting the requirement for healthy growth, maintenance and productivity of the body system. However, poultry meat production in Nigeria is at a level below the capacity to meet the demand of the ever increasing population. Ojo (2003) revealed that the poultry industry is incapable of meeting the animal protein consumption index in the country, which is estimated to be about 5 g/caput per day. This is quite meage, considering the FAO recommended level of 35 g/caput per day.

With the country's under-production rate and attempt to meet up with the increasing demand intensity, the bulk of poultry meat demands are met by importation from other countries (Odutan, 2015). Tonnes of poultry meat are imported through illegal means into Nigeria daily, despite it being one of the topmost products on the import prohibition list of Nigeria (Sahel, 2015). This stems from the huge gap that exists in the production capacity of different countries, which provides an impetus for the smuggled poultry product business. Nonetheless, the aspect of food safety could easily be overlooked in such a system.

Food safety is a foremost global concern, particularly within the preceding decade and current period. High-quality poultry meat is expected to be free of every kind of biological, chemical and physical contamination (Ingr, 1989). This has resulted in increasing examination regarding the risk associated with consumption of victuals contaminated with microorganisms, pesticides, heavy metals and/or toxins (Hussain *et al.*, 2012).

Occurrence of heavy metal impurities in poultry meat has been credited to the utilization of a variety of technological inputs during production (Thirulogachandar *et al*., 2014) such as rearing in contaminated surroundings, enhanced feeding modification and processing practices.

Another contaminant receiving increasing attention is formaldehyde; a toxic and volatile aldehyde. Formaldehyde has numerous industrial applications, inclusive of feed to improve management characteristics (WHO, 2002). Formaldehyde is used as a preservative, disinfectant, biocide, bleaching agent and antibacterial against spoilage and pathogenic food microorganisms like bacteria, moulds and yeasts. Certain poultry producers and merchants deliberately include formaldehyde, to serve as a preservation measure against spoilage of their products, especially in setups where refrigeration happens not to be adequately available or where there is the possibility of a breakdown in the cold chain resulting in spoilage of frozen poultry products (Otuh *et al*., 2013).

Formaldehyde can affect food quality as a result of its unpleasant attributes capable of causing injurious effects on consumers. The International Agency for Research on Cancer (2006) classified formaldehyde as a known human carcinogen. It can result in health problems such as vomiting, pain, allergy, bleeding, kidney failure, effects on central nervous system and coma. McGwin *et al.* (2010) showed a strong connection between exposure to formaldehyde and the development of childhood asthma.

There is a mounting awareness on the exposure to heavy metal toxicity from meat products as a result of contamination of soils, plants and the environment in which the meat is processed (Huang *et al*., 2009; Zhuang *et al*., 2014). Foremost heavy metals which gather in food chain and have a cumulative effect are lead, cadmium, mercury and arsenic (Cunningham and Saigo, 1997) which are then deposited in the flesh, and soft organs (liver and kidney), eventually getting into the food chain when consumed as meat by humans. Jarup (2003) revealed that heavy metals are not biodegradable and are likely to accumulate in diverse body organs leading to unwanted effects, such as cardiovascular, kidney, nervous and bone diseases. With the growing health concern in Nigeria about smuggled imported poultry meat, there is the necessity for concerns about the safety and quality of the imported poultry meat in comparison to the locally produced counterpart.

This study aimed to determine the heavy metals (Lead, Cadmium, Chromium, Mercury) and formaldehyde contamination status of poultry meat samples in selected cities (Abuja, Lagos, Port-Harcourt, Ibadan) in Nigeria, providing scientific evidence to foster the need for tighter poultry meat quality control and strengthening of regulatory and enforcement measures.

Materials and Methods

Sample collection

A total of 56 meat samples were obtained; consisting of 24 imported frozen turkey wings, 12 from privately owned poultry meat retailers and the other 12 from privately owned frozen poultry meat wholesalers. Another 24 imported frozen chicken leg samples including the thigh and drumstick; 12 also from privately owned commercial poultry meat retailers and another 12 from privately owned frozen poultry meat wholesalers. Eight samples of locally bred chicken were obtained from supermarkets and poultry processors. The samples were collected in sterile plastic bags, kept on ice in insulated boxes and transported to the laboratory for analyses.

Digestion of sample

To carry out the wet digestion of sample, 5.0 g of sample oven-dried at 105°C for 24 hours was emptied into the digestion glass tube. Ten millimeters of H_2SO_4 was added to the meat samples and left overnight at room temperature. Then 4.0 ml perchloric acid ($HClO_4$) was added to the mixture and kept in the fume block for digestion. The temperature was gradually increased from 50ºC up to 300ºC. The complete digestion of the mixture was indicated by the appearance of white fumes. The mixture was left to cool and transferred to 100 ml volumetric flasks and the volumes of the contents were made up to 100 ml mark with distilled water. The digested solution was transferred to plastic bottles labeled accurately and later used for heavy metal determination.

Heavy metals Determination

The digested sample was analyzed for Lead, Cadmium, Chromium and Mercury by Perkin-Elmer Analyst 300 Atomic Absorption Spectrophotometer according to the method of AOAC (2003) in the Nutrition Laboratory of the Department of Animal Science, University of Ibadan. Different electrode lamps were used for each element. The concentration of heavy metals was recorded in mg/kg.

Formaldehyde determination

Preparation of reagents

A Mixture of 15 g potassium metabisulphite ($K_2S_2O_5$) with 70 ml concentrated HCl was prepared and made up to 1 L with distilled water (Solution A). To prepare (Solution B) 200 g sodium phosphate (Na_3PO_4) and 4.5 g EDTA were mixed and made up to 1 L volume. For solution C, 250 ml conc. HCl was added to 1 litre of water. While Solution D was prepared by mixing 100 g boric acid with 170 g sodium hydroxide, adding water to dissolve and then made up to 1 L volume.

Formaldehyde detection

A 500 ml capacity graduated flask was filled to the 300 ml mark with boiled and cooled water to which, 10 ml of reagent A, 50% ethanol and 50 ml of sample distillate was added. The flask was stoppered, then swirled to homogenize and allowed to stand for 15 min. Following this, 10 ml of solution B was added and the mixture was swirled to thoroughly mix the contents and then allowed to stand for another 15 min in the covered flask. Then 10 ml of solution C and 10 ml fresh starch solution (0.2%) was added and swirled to mix thoroughly. Iodine (approx. 0.1 m) was added to the solution in order to eliminate any excess bisulphate bringing the solution to a faint blue end point. Thereafter, 10 ml of solution D was added. The liberated bisulphate was then titrated with 0.05 M iodine to the same faint blue end point. Total formaldehyde was calculated thus:

$$\text{Total formaldehyde} = \frac{\text{Titre x 2.2}}{S}$$

(Where S is the alcoholic strength of the sample in percent)

Statistical Analyses

Data were analyzed with descriptive statistics and one way analysis of variance (P<0.05) to determine if heavy metals and formaldehyde concentration varied significantly across sources. Means were separated by Duncans Multiple Range Test at P<0.05.

Results

The results of heavy metal concentrations in legs of chicken sampled in Abuja, Lagos, Port-Harcourt and Ibadan are presented in Table 1. The concentration of Pb ranged between 0.0004 and 0.0238 mg/kg; 0.0 and 0.0103 mg/kg Cd; 0.0024 and 0.0413 mg/kg Cr and 0.0 and 0.0020 mg/kg Hg. Lead concentration in chicken meat was highest in Lagos followed by Abuja. Meat from locally produced chicken had the lowest (P<0.05) lead concentration and had similar lead concentration with chicken meat collected from Ibadan. There was significant difference (p<0.05) among all the values obtained for lead present in the imported chicken legs in Lagos, Port-Harcourt, Ibadan and Abuja cities, but the locally produced chicken 0.0061 mg/kg and that of Ibadan (0.0004 mg/kg) which had the least Pb concentration showed no significant difference (p<0.05). Cadmium concentration in chicken meat from Lagos, Abuja and Port-Harcourt were significantly higher than concentrations in Ibadan and what was obtained from locally produced chicken. Chromium concentration was significantly higher in Lagos and Abuja chicken samples compared to other chicken samples, with the locally produced sources having the lowest (P<0.05) concentration. Mercury was not significantly different among all the samples of chicken.

Table 2 shows the mean concentration of heavy metals in turkey wing samples obtained from various sources. The concentration of Pb ranged between 0.0023 and 0.0246 mg/kg; 0.0008 and 0.0100 mg/kg Cd; 0.0128 and 0.0389 mg/kg Cr and 0.0001 and 0.0031 mg/kg Hg. Pb Cd and Cr concentrations from Ibadan samples were significantly lower than those collected from other locations. For mercury however, the highest concentration was in

Table 1: Heavy metals concentration in chicken thighs (mg/kg) sampled from Lagos, Abuja, Port-Harcourt and Ibadan

Sources	Lead	Cadmium	Chromium	Mercury
Lagos	0.0238 ± 0.0066^{ns}	0.0103 ± 0.0039^{ns}	0.0413 ± 0.0089^{ns}	0.0006 ± 0.0003^{ns}
Abuja	0.0195 ± 0.0063^{ba}	0.0083 ± 0.0062^{ns}	0.0360 ± 0.0073^{ns}	0.0017 ± 0.0032^{ns}
Port-Harcourt	0.0137 ± 0.0073^{b}	0.0097 ± 0.0067^{ns}	0.0188 ± 0.0121^{b}	0.0020 ± 0.0028^{ns}
Ibadan	0.0062 ± 0.0037^{c}	0.0018 ± 0.0027^{b}	0.0200 ± 0.0105^{b}	0.0002 ± 0.0003^{ns}
Locally produced	0.0004 ± 0.0011^{c}	0.0000 ± 0.0000^{b}	0.0024 ± 0.0032^{c}	0.0000 ± 0.0000^{ns}

Means with different superscript letters on the same column are significantly different using Duncans' multiple rage test (P<0.05)

Table 2: Heavy metals concentration (mg/kg) in imported turkey meat (wings) sampled from Lagos, Abuja, Port-Harcourt and Ibadan

Sources	Lead	Cadmium	Chromium	Mercury
Lagos	0.0246 ± 0.0073^{a}	0.0100 ± 0.0038^{a}	0.0389 ± 0.0076^{a}	0.0004 ± 0.0003^{b}
Abuja	0.0241 ± 0.0038^{a}	0.0065 ± 0.0057^{a}	0.0351 ± 0.0093^{ba}	0.0031 ± 0.0025^{a}
Port-Harcourt	0.0211 ± 0.0077^{a}	0.0086 ± 0.0033^{a}	0.0260 ± 0.0055^{b}	0.0008 ± 0.0020^{b}
Ibadan	0.0023 ± 0.0035^{b}	0.0008 ± 0.0020^{b}	0.0128 ± 0.0076^{c}	0.0001 ± 0.0010^{b}

Means with different superscript on the same column are significantly different (p<0.05)

Table 3: Formaldehyde concentration (mg/kg) in turkey and chicken meat sampled from Lagos, Abuja, Port-Harcourt and Ibadan

Sources	**Turkey**	**Chicken**
Lagos	158.17 ± 14.25^{c}	158.45 ± 15.16^{b}
Abuja	196.56 ± 13.36^{a}	196.56 ± 13.36^{a}
Port-Harcourt	180.83 ± 12.99^{b}	188.50 ± 5.52^{a}
Ibadan	154.28 ± 12.90^{c}	151.45 ± 9.03^{b}
Locally Produced	ND	ND

Means with different superscript on the same column are significantly different (p<0.05)
ND- Not detected.

samples from Lagos and it was significantly higher than the concentration from other locations.

The formalin distribution in imported turkey and chicken sampled in various cities are presented in Table 3. Significantly higher concentration were detected in both turkey and chicken products collected from Abuja and Port-Harcourt with Lagos and Ibadan samples having lower concentrations.

Discussion

Lead (Pb) is considered an extremely toxic metal, due to the devastating health concerns it is capable of causing. It is found in diverse products such as paints, water pipes, petroleum products, cosmetics and food. Lead was detected in all the poultry meat samples. Imported chicken thighs and imported turkey wings in Lagos city had the highest Pb concentration. The possibility of the huge markets in the large city resulting from insufficient products might lead to inadequate scrutiny on quality of poultry products. It could also be as a result of variation in production materials such as: feed consumed, water sources and processing activities possibly influencing the products. The Pb concentration of 0.10±1.55-7.85± 0.54 mg/kg was discovered in various brands of poultry feeds in south eastern Nigeria (Okoye *et al.,* 2011). The Pb concentration values were low when compared with that recovered from chicken meat by Iwegbue *et al. (*2008) which varied at different locations in southern Nigeria, except for lead concentration in imported chicken thigh and turkey wings in Lagos, Port-Harcourt and Abuja cities. Also, Akan *et al.* (2010) observed lead concentration of 0.1 µg/g in the livers of chicken in Nigeria but the concentrations of heavy metals in organs were not investigated in this study. Pb concentration in all the chicken samples was below the acceptable level of 0.5 ppm (mg/kg) established for Pb (European Union Regulation (EC) No 1881/2006).

The concentrations of lead in the liver, kidneys and most meat products have been documented in other countries. Hussain *et al.* (2012) observed high concentration of lead to as high as 3.27µg/g for Pb in chicken liver in Iraqi city, which were mainly imported. Gonzalez-Weller *et al*. (2006) detected concentrations as high as 6.94 ± 4.63 mg/kg in Spain from chicken meat.

Lead concentration in the turkey wings was higher, compared to that observed in chicken thigh which could be because turkey takes longer time to attain maturity than chicken, thereby accumulating more heavy metals in their body. Lead is capable of causing harm to the body in both small and high concentrations (Salem *et al.,* 2000). Lead toxicity can result in damage to the central nervous system, kidney and eventually result in death (Jennings *et al.,* 1996).

Results showed similarities in cadmium content in both imported chicken thigh and turkey wings across the different sources. The range of cadmium level in the imported turkey wings observed in Lagos, Port-Harcourt and Abuja showed no significant difference. Lagos city also had the highest cadmium concentration in both the chicken thigh and turkey wing samples (0.0103 mg/kg and 0.0100 mg/kg). Imported chicken thighs and turkey wings from Ibadan city were lower in cadmium concentration (0.0018 mg/kg and 0.0008mg/kg). However, no deposit of cadmium was determined in the locally sourced chicken. The permissible limit set for cadmium in poultry meat is 0.05 mg/kg (European Union Regulation (EC) No 1881/2006). This indicates that the cadmium concentration in the turkey thighs and chicken wings fell below the maximum tolerable limit. Cadmium concentration in imported chicken from the various cities were similar to that observed by Abdolgader *et al.* (2013) in chicken in Libya. Salwa *et al.* (2012) noted Cadmium concentration of 0.15 µg/g in the pectoral muscle of chicken. Alkhalaf *et al.* (2010) observed Cadmium range of 0.083 mg/kg to 0.249 mg/kg while Okoye *et al.* (2011) reported cadmium in the range of 0.038±0.08 mg/kg to 0.0463±0.2 mg/kg in various types of feed fed to poultry animals based on their stages of growth in Saudi Arabia and south eastern Nigeria, respectively. This indicates that feed could contribute to the cadmium contamination in poultry meat.

Cadmium is usually not present in human body at birth; however it accumulates with age (Akan *et al.,* 2010). It then interacts with a number of minerals mainly Zn, Fe, Cu and Se due to chemical similarites and competition for binding sites (McLaughlin *et al.,* 1999).

Cadmium can build up in the body of humans and harmfully influence the liver, kidney, lung, bones, placenta, brain and the central nervous system (Castro-González and Méndez-Armenta, 2008). The International Agency for Research on Cancer has classified Cadmium as a human carcinogen on the basis of occupational studies (EFSA, 2009).

Chromium is vital to man and animal but in surfeit can result in toxicity. Food is a means by which chromium is taken into the body. Locally sourced chicken had chromium concentration of 0.0023 mg/kg which is lower compared to the imported poultry meat from various sources. Imported turkey wings (0.0398mg/kg) and imported chicken (0.0413 mg/kg) from Lagos had the highest concentration of chromium of all the meat samples analysed. Imported turkey wings from Ibadan (0.0128 mg/kg) had the least chromium concentration. In the current study, concentration of chromium was lower than the permissible level of 1 mg/kg (European Union Regulation (EC) No 1881/2006). Abdullahi *et al.* (2013) and Thirulogachandar (2014) reported higher concentration of chromium in selected tissues of adult chicken layers, chicken muscle and liver above the acceptable permissible limit and concentration values noted in turkey wings and chicken thighs in the present study. Chromium was discovered in beef, mutton, caprine and chicken from a market in Borno State, Nigeria, with the highest concentration in the liver of caprine (1.22±0.21 µg/g) and the lowest level was observed in beef 0.23 µg/g (Akan *et al.,* 2010).

Mercury can get into food as a result of human activities such as industrial and agricultural processes. Mercury had least level contamination of all the heavy metals analyzed in this study. No trace of mercury was observed in locally sourced chicken samples. Abuja had the highest mercury concentration in imported turkey wings and Port-Harcourt in imported chicken wings. Presently, no tolerable level has been established for Mercury contamination in poultry meat but the Tolerable Weekly Intake for methylmercury should be below 1.6µg/kg body weight (JECFA, 2003). Batista *et al.* (2012) recorded higher levels of 0.5-30 *ng* THg/g in Brazil in chicken meat and Ghimpețeanu (2012) reported of 0.04 to 2.77µg/kg concentration in poultry liver samples.

Mercury is a prevalent and persistent contaminant in the environment and is one of the extremely harmful trace metals in human food chain (Ghimpețeanu, 2012). Mercury is being utilized as agricultural fertilizer and soil conditioner, this creates the possibility of introducing this heavy metal into food products and feeds for farm animals, also, it's a steady constituent of municipal sewage (Zarski *et al.,* 2003; Tuzen *et al*., 2009). The chemical forms (ionic < metallic <organic) of heavy metals determines their toxicity (Clarkson, 2006). Absorption of Organic mercury compound is mainly from food (Reilly, 2007). Organic mercury e.g. methylmercury, has effects on the brain and intellectual advancement in young children (FSAI, 2009).

All imported chicken and turkey meat contained formaldehyde in various concentrations. The locally produced chicken had no detectable formaldehyde level. IARC (1995) revealed that formaldehyde is available in small intensity in a good number of living organisms due to being a metabolic intermediate. Higher concentrations of formaldehyde occur naturally in a number of fruits and marine fish. The result on formalin detection showed that imported chicken samples from Lagos, Abuja, Port-Harcourt and Ibadan contained formalin in 158.45, 196.56, 188.50 and 151.45 mg/kg, respectively. Samples from Abuja had the highest formalin concentration, while those from Ibadan had the least formalin concentration in imported chicken thigh. For the imported turkey wings, Abuja (196.56 mg/kg) samples also had the highest formalin concentration, with Ibadan (154.28 mg/kg) having the least concentration. Formaldehyde affects the structural quality of muscle foods. During frozen storage of products containing formaldehyde, chemical enzymatic reduction of trimethylamine-Noxide to formaldehyde and dimethylamine occurs (Sotelo *et al.,* 1995), especially in fish. The likelihood of increased concentration of formalin in samples obtained in Abuja may be as a result of ease of disruption in the cold chain. It is also likely that smuggled poultry produced consumed along border towns in Nigeria are likely to have reduced formalin content. Apart from the implications of formalin on human health, formalin reacts with protein muscle resulting in muscle hardiness and protein denaturing and thereby increasing protein solubility (Leelapongwattana, 2005).

The similar values observed between the formalin content in the turkey wings and chicken thigh could be attributed to similarities in product source. In most cases, similar production companies and business merchants are in charge of importing both chicken and turkey meat into the country. The maximum daily intake of formaldehyde set by United States Environmental Protection Agency was 0.2 mg/kg body weight (Xuang *et al.,* 2009). Siti *et al*. (2013) observed that washing formaldehyde contaminated product in running tap water reduces the formaldehyde concentration because formaldehyde is water soluble also it gets evaporated easily during cooking (Bianchi, 2007). Even though the concentration of heavy metals and formaldehyde are less than the acceptable limits, the fact that they are present is cause for concern as these metals and the preservative can be accumulated in human bodies when products are heavily and regularly consumed. The levels of these toxicants needs to be regularly monitored to ensure that they remain below acceptable limits of regulatory bodies.

Conclusion

Locally produced chicken flesh contained heavy metals Lead and Chromium but in a lower concentration compared with the imported counterpart. Mercury and Cadmium was not detected in the locally produced meat. Although, in all cases, the heavy metal concentration were below the maximum tolerable limits set by control agencies. However, heavy metals have the tendency of bioaccumulation and when there is a continuous exposure of the body to such metals, it results in toxicity which could have debilitating effect on humans' health. All the imported poultry meat samples contained formaldehyde, while it was not detected in the locally produced ones.

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