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Presence of Heavy Metals in Pork Products in Chennai (India)

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Abstract: The presence of heavy metals in frozen and canned commercial pork products obtained from retail outlets of Chennai city was determined, by atomic absorption spectrophotometry using dry ashing method. The samples had cadmium from 0.038 to 0.545 mg kg^{-1}, chromium up to 2.244 mg kg^{-1}, copper up to 2.847 mg kg^{-1}, lead up to 6.290 mg kg^{-1} and zinc from 6.927 to 144.575 mg kg^{-1}. Generally, heavily spiced products had higher levels of heavy metals. Levels of cadmium exceeded the Maximum Permissible Level (MPL) of 0.1 mg kg^{-1} in 95.83% of the samples as stipulated by Food and Agriculture Organization (0.1 mg kg^{-1}), whereas no samples had copper content exceeding MPL (20 ppm) specified by Meat Food Products Order (MFPO), 25.0% of the samples had lead content exceeding the limit specified by MFPO (2.5 ppm) and 20.83% of the samples had zinc values exceeding the MPL of MFPO (50 ppm). The results of this study demonstrate the need for good manufacturing practices (GMP's) and HACCP to control these heavy metals in pork products.

Key words: Pork products, heavy metals, chromium, cadmium, zinc, lead, copper, atomic absorption spectrophotometry

INTRODUCTION

The risk associated with the exposure to heavy metals present in food products had aroused widespread concern in human health. Improvements in the food production and processing technology had increased the chances of contamination of food with various environmental pollutants, especially heavy metals. Ingestion of these contaminants by animals causes deposition of residues in meat. Due to the grazing of cattle on the contaminated soil, higher level of trace metals have been recorded in beef and mutton (Sabir *et al*., 2003). Presence of substantiate levels of toxic metals lead and cadmium in meat products have been recorded (González-Weller *et al*., 2006).

Over the past few decades, both developed and developing countries have experienced equally life and food style changes that have led to an increased demand for processed foods. Some heavy metals get deposited in food as residues during processing (WHO, 1987). When the residue levels go beyond the prescribed standards, they cause deleterious effects on human health, especially when consumed continuously. Hence, food safety can be ensured only by keeping the contamination as low

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as possible. In the recent times, consumption of pork products has been on the increase in Chennai city. This study was undertaken to determine the levels of heavy metals like cadmium, chromium, copper, lead and zinc in commercially available pork products and to compare the levels of these chemical residues with the specified standards.

MATERIALS AND METHODS

Forty eight samples of commercial pork products, viz., bacon, ham, sausage, salami and canned luncheon meat were obtained from the retail outlets in Chennai city and were examined for the presence of residues of heavy metals.

The samples were allowed to thaw for 16 h at 2°C and 200 g from each product were homogenised in a domestic mixer grinder. Sub-samples were taken out of these representative samples for determining heavy metals. An accurately weighed sample of about five grams of each sample was taken in vycor crucibles to which 2.5 mL of 50% w/v of magnesium nitrate hexahydrate was added. They were then dried for 6 h at 70-75°C and ashed in muffle furnace at 500°C for 1 to 2 h. The ash was again kept in muffle furnace at 500°C after wetting with concentrated nitric acid. The wetting procedure was repeated until the ash turned white in colour. The ash was then made up to 10 mL with triple glass distilled water after adding 1 mL of concentrated nitric acid and two 1 mL portions of dilute (1+3) nitric acid. The stock standard solutions and the working solutions were prepared as per the Cook Book (1982) Perkin-Elmer by utilizing the triple glass distilled water.

Atomic Absorption Spectrophotometer (AAS)-(Perkin Elmer model 2380) was used for estimating the metals. The concentration of the metal to be determined was provided between 0.1 to 0.5 absorbance units. According to the absorbance, the concentration was calibrated and the concentration was measured directly when the sample was within the linear working range. Presence of heavy metals was estimated using respective hollow cathode lamps to give lamp energy. The fuel oxidant was obtained by acetylene - air mixture which provided the flame for determination of metals. For all elements, the fuel/oxidant ratio was used as prescribed. The standard conditions and instructions detailed in analytical methods were followed.

The mean and the standard error were calculated as per the methods outlined by Snedecor and Cochran (1994) and compared with the available standards of maximum permissible limits by using single sample t-test by keeping the corresponding available standards as test value.

RESULTS AND DISCUSSION

Cadmium

The canned luncheon meat had the highest mean cadmium level, followed by salami (0.296 mg kg^{-1}) and sausage (0.238 mg kg^{-1}). The observed mean values of the individual products and overall mean of all the products were significantly ($p<0.05$) higher than the MPL of 0.1 mg kg^{-1} (Table 1). In earlier studies on various ready to eat cured meat products and muscle of food animals,

Table 1: Mean cadmium levels (mg kg^{-1}) in Pork products

Product	n	Mean±SE	Observed values Minimum	Observed values Maximum	p-value (test value = 0.01 mg kg^{-1})
Bacon	10	0.220±0.031	0.038	0.374	0.004
Ham	10	0.230±0.023	0.122	0.329	0.000
Sausage	17	0.238±0.030	0.065	0.545	0.000
Luncheon meat	3	0.320±0.032	0.281	0.384	0.021
Salami	8	0.296±0.036	0.161	0.479	0.001
Overall (mg kg^{-1})	48	0.247±0.015	0.038	0.545	0.000

n: No. of observations, SE: Standard Error

the cadmium levels were recorded in the range of 0.01 to 0.42 mg kg^{-1} (Kirkpatrick and Coffin, 1973) and 0.1 to 0.2 mg kg^{-1} (Coleman *et al*., 1992), respectively. Contamination of meat products with cadmium might occur in three ways, one from animals grazing on lands spread with sewage sludge or phosphate fertilizers and another from animals grazing on lands contaminated with industrial cadmium effluent (Yost, 1984; Koh and Judson, 1986). The cadmium-contaminated mineral components of commercial feeds and phosphate fertilizers (Linden *et al*., 2001) were found to have strong correlation to concentrations in animal tissues (Sharma *et al*., 1982). Cadmium from the soil could reach man through vegetables, milk and meat (Stenstrom and Lonsjo, 1974). The main cause of the *Itai-Itai* disease in Japan was the high concentrations of cadmium in rice over long time as the soil in the valley was polluted with sludge from a nearby mine. Secondary cadmium contamination of food occurs as a result of its use in food processing (Zurera-Cosano, 1993). Muller *et al*. (1996) reported that sausages had higher cadmium content than the raw meat. The addition of spices during production of sausages might be the main reason since spices could contain cadmium concentrations up to 200 ng g^{-1} (Muller *et al*., 1992).

In this study, sausages and salami were highly spiced and comminuted products and they were found highly contaminated with cadmium. The fact that the luncheon meat had the highest concentration of cadmium among the products analyzed could be due to the processes involved during canning. The lower levels in bacon and ham could be due to the non-addition of spice mix and absence of communication in the product making. In this study, 95.83% of the samples exceeded 0.1 mg kg^{-1} and 64.58% of samples exceeded 0.2 mg kg^{-1} of cadmium.

A hypothesis has also been put forward that cadmium could play a role in the development of cardiovascular diseases, particularly hypertension. Chronic exposure to cadmium could cause nephrotoxicity in humans, mainly due to abnormalities of tubular re-absorption (Nordberg, 1999). The biological half life of cadmium in the human kidney is long and has been estimated to be 10 to 30 years (Fox, 1987). Due to the slow excretion of the metal, the concentration in the kidney would gradually increase, even at very low concentrations in the food. It has been calculated that with a daily cadmium intake of 250-350 μg, a man might reach hazardous concentrations at the age of 50, with a risk of renal damage (Frieberg *et al*., 1974)

In practice, cadmium levels found in food are normally below 0.1 mg kg^{-1} (FAO, 1980). The MPL prescribed in Australia for cadmium in muscle of livestock and poultry is 0.2 ppm (Coleman *et al*., 1992).

Chromium

The highest level of chromium (2.244 mg kg^{-1}) was observed in pork salami samples (Table 2). Bacon (0.68 mg kg^{-1}), salami (0.65 mg kg^{-1}) and canned products (0.60 mg kg^{-1}) (luncheon meat) had higher chromium content than ham and sausage. Statistical analysis revealed that the observed mean values of the individual products and overall mean were significantly ($p<0.05$) higher than the MPL (0.05 mg kg^{-1}) (Codex Alimentarius Commission, 1994). Maggi *et al*. (1979) observed ten times higher chromium content in canned products, compared to fresh beef probably due to release of the metal from tins, while Marriot *et al*. (1982) observed it to be below the detectable level in beef and pork frankfurters. But in the present study the chromium content of sausages was up to 1.309 mg kg^{-1}. As the ingested chromium is found mainly in liver, kidneys and blood (Khitrov and Jaeger, 1995), the use of organ meat might increase the chromium content. Tinggi *et al*. (1997) reported a chromium content of 12 to 50 ng kg^{-1} in various meat products. Khitrov and Jaeger (1995) documented that dermatosis, nephritis and liver damage were the results of absorption of large quantities of chromium over a long period. Kidney damage has also been observed in animal studies. Chromium is a potent allergen and is a common skin sensitizer in allergic eczema (Anderson, 1993). Although no MPL has been prescribed by Meat Food Products Order (MFPO, 1973) for chromium in food products, the MPL

Table 2: Mean chromium levels (mg kg^{-1}) in Pork products

Product	n	Mean±SE	Observed values Minimum	Observed values Maximum	p-value (test value = 0.05 mg kg^{-1})
Bacon	10	0.679±0.141	0.022	1.733	0.002
Ham	10	0.370±0.099	BDL	0.882	0.011
Sausage	17	0.536±0.092	BDL	1.309	0.000
Luncheon meat	3	0.598±0.108	0.474	0.812	0.036
Salami	8	0.650±0.246	0.101	2.244	0.045
Mean (mg kg^{-1})	48	0.554±0.063	BDL	2.244	0.000

n: No. of observations, BDL: Below Detectable Level

Table 3: Mean copper levels (mg kg^{-1}) in pork products

Product	n	Mean±SE	Observed values Minimum	Observed values Maximum	p-value (test value = 20 mg kg^{-1})
Bacon	10	1.005±0.170	0.281	1.937	0.000
Ham	10	1.283±0.253	0.527	2.847	0.000
Sausage	17	0.928±0.143	BDL	2.171	0.000
Luncheon meat	3	0.716±0.243	0.422	1.198	0.000
Salami	8	1.199±0.151	0.768	1.754	0.000
Mean (mg kg^{-1})	48	1.050±0.087	BDL	2.847	0.000

n: No. of observations, BDL: Below Detectable Level

in mineral water has been specified as 0.05 mg L^{-1} by the (Codex Alimentarius Commission, 1994). In the present study the levels of chromium estimated in the pork products are higher when compared to this level. Owing to the toxic effect of this metal, strict regulations and screening methods have to be implemented.

Copper

Out of 48 samples, 45 samples had copper levels of below 2 mg kg^{-1} (Table 3), which was in accordance with the results shown by Larkin *et al.* (1954), Rajmane *et al.* (1986) and Brito *et al.* (1990). Statistical analysis implied that the observed mean values of all the products were significantly lower ($p<0.01$) than the MPL (MFPO, 1973) (20 ppm). In this study, the mean copper level was the highest in ham followed by salami and bacon. Rajmane *et al.* (1986) reported a higher concentration in salami samples (13.8 ppm) and in ready-to-eat meat products and concluded that the main source of contamination of foods with copper was copperware used to store or cook foods. Copper, although not essentially toxic, could cause public health hazards in high concentrations (Brito *et al.*, 1990). In humans, 10-30 mg of orally ingested copper from foods stored in copper vessels might cause intestinal discomfort, dizziness and headaches, while excess accumulation of copper in liver may result in hepatitis or cirrhosis and in a hemolytic crisis similar to that seen in acute copper poisoning (Johnson, 1993). However none of the samples in this study had copper content exceeding the MPL (20 ppm) prescribed by MFPO (1973) in meat products.

Lead

The present study revealed lead levels being significantly ($p>0.05$) closer to the MPL (MFPO, 1973) (2.5 mg kg^{-1}) in ham, bacon and salami, while sausages had significantly lower ($p<0.05$) levels (Table 4). Luncheon meat had significantly higher ($p>0.05$) levels of lead. The lead levels determined in this study were in accordance with that of Rajmane *et al.* (1986) and Brito *et al.* (1990). Among the samples studied, 41.67% samples had lead levels between 2.0-7.0 mg kg^{-1} which was similar to the results of Rajmane *et al.* (1986). The canned meat products had higher lead contents and the highest lead content of 6.29 mg kg^{-1} was recorded in canned luncheon pork. Similar findings in canned meat products were reported by Dabeka and McKenzie (1995) and Muller and Anke (1995). The higher lead content of the canned products might be due to the release of a substantial quantity of lead, probably from the soldering line into the food (Maggi *et al.*, 1979; Larkin *et al.*, 1954). Other than the canned meat products, some of the other products also had higher lead content (2.500-5.000 mg kg^{-1}),

Table 4: Mean lead levels (mg kg^{-1}) in Pork products

Product	n	Mean±SE	Observed values Minimum	Observed values Maximum	p-value (test value = 2.5 mg kg^{-1})
Bacon	10	1.641±0.406	BDL	3.399	0.064
Ham	10	1.966±0.463	BDL	4.542	0.279
Sausage	17	1.352±0.257	BDL	3.948	0.000
Luncheon meat	3	3.250±1.525	1.505	6.290	0.671
Salami	8	2.231±0.432	BDL	3.479	0.554
Mean (mg kg^{-1})	48	1.805±0.198	BDL	6.290	0.001

n: No. of observations, BDL: Below Detectable Level

Table 5: Mean zinc levels (mg kg^{-1}) in Pork products

Product	n	Mean±SE	Observed values Minimum	Observed values Maximum	p-value (test value = 50 mg kg^{-1})
Bacon	10	43.964±9.493	10.644	100.329	0.541
Ham	10	34.813±7.161	7.859	83.757	0.063
Sausage	17	35.718±8.707	6.927	144.575	0.120
Luncheon meat	3	27.308±8.762	11.628	41.923	0.122
Salami	8	33.486±4.867	15.627	53.856	0.012
Mean (mg kg^{-1})	48	36.350±3.998	6.927	144.575	0.001

n = No. of observations

probably due to the presence of higher levels of lead in the raw meat itself. Lead concentrations in tissues were found to be higher in samples obtained from sheep raised in former mining areas than in other samples (Schroeder, 1991). Oskarsson *et al.* (1992) reported a high lead concentration (500 μg kg^{-1}) in beef after accidental exposure to lead. Vreman *et al.* (1988) found higher concentrations of lead in the muscle of dairy cows raised on pasture than in the muscle of dairy cows kept indoors. Humphreys (1991) reviewed the effects of lead in animals and reported that due to its slow rate of elimination, harmful levels of lead could accumulate in tissues after prolonged exposure to even low quantities of lead. The most hazardous heavy metal monitored on the swine farms in the district of Hodonín, Czech Republic in 1994-1999 was lead, the major source of which being paint coats containing more than 0.6 g lead kg^{-1}, mineral components of commercial feeds, scrap lead batteries put away in barns and lead-coated guide bars of electric lines (Ulrich *et al.*, 2001). Secondary contamination of food may occur due to processing and addition of spices. Except bacon and ham, pepper which contains higher levels of lead (>2.5 ppm) (Larkin *et al.*, 1954) had been added invariably to almost all types of meat products. Muller and Anke (1995) reported that the lead content of sausage was higher than that of the meat used for its production, presumably due to the spices used in sausage production. Bolger *et al.* (1996) reported that infants and children are more susceptible to lead toxicity than adults because they consume more food per unit of body mass, with the lead getting absorbed more readily. The half life of lead in blood, soft tissues, spongy bones (pelvis, ribs and skull) and cortical bones (mid tibia and mid femur) is 35, 40 days, 3-5 and 30 years, respectively (Pueschel *et al.*, 1996). Tuormaa (1995) reported that an excessive lead accumulation in children is known to cause hyperactivity, reduced intelligence and antisocial behaviour. In adults it is associated with heart disease, cancer and infertility. Lead could cause adverse effects on the renal and nervous systems and cross the placental barrier, having potential toxic effects on the fetus (Tuormaa, 1995; WHO, 2003). In the present study, 25.0% of the samples had lead content exceeding the MPL.

Zinc

MFPO (1973) has specified the MPL of zinc in meat product as 50 ppm. In the present study, 79.17% of samples had zinc levels below 50 mg kg^{-1} which is in accordance with the results of Larkin *et al.* (1954), Osis *et al.* (1972), Brito *et al.* (1990) and Simakova *et al.* (1993) who determined the zinc levels in the meat products. Similar results were also reported in fresh meat samples of various food animals (Coleman *et al.*, 1992; Jayasekara *et al.*, 1992). Only 14.58% of samples had values

between 50-100 mg kg^{-1}. Langlands *et al.* (1987) observed a zinc level upto 70 and 57 mg kg^{-1} in muscle of cattle and sheep, respectively. Simakova *et al.* (1993) reported a zinc level upto 83.2 mg kg^{-1} in beef and 5.4 mg kg^{-1} in pork (Table 5). Food and diets high in protein were found to have high zinc (Osis *et al.*, 1972). The major source of readily bioavailable zinc in the US diet is beef (Welsh and Marston, 1982). The second most important source is pork (Pekarinen, 1973). Leita *et al.* (1991) reported that zinc content of sheep grazing in zinc smelter areas generally had higher zinc content in muscles of and the samples of pasture had 200 ng g^{-1} of zinc. Larkin *et al.* (1954) reported relatively higher levels of zinc in a number of spices and curry powders, which might also increase the zinc content of the food products. Ellis *et al.* (1984) found that storage of wet, damp brewer's grains, in used galvanized feed bins even for 24 h could result in zinc levels over 100 ppm in the material near the galvanized surface of the container. Except salami, all other observed pork products had the mean zinc levels significantly ($p>0.05$) approaching the MPL. In salami, the observed mean level of the zinc was significantly ($p<0.05$) lower than the MPL. The abnormally high levels of zinc found in a few samples might be due to the use of galvanized equipment or vessels. Diets deficient of copper and zinc may cause clinical manifestations whereas increased levels could accumulate in target organs such as liver and kidneys of living organism resulting in toxic effects (Cherian and Nordberg, 1983). Klevay (1977) hypothesized that high dietary zinc to copper ratio might be a contributing factor in the development of coronary heart disease. In this study, 20.83% of the samples had zinc values exceeding MPL.

CONCLUSIONS

The present study depicts the scenario of the heavy metal levels in selected pork products. The levels of cadmium and lead, which are hazardous metals, exceeded the MPLs in 95.83 and 25.00% of the samples, respectively. Even though, there is no prescribed limit for chromium in the food products, about 95.83% samples exceeded the limit prescribed for drinking water. About 79.17% of samples had zinc levels below 50 mg kg^{-1} (MPL). None of the samples had copper content exceeding the MPL (20 ppm). Hence, the results of this study demonstrate the need for a systematic control of toxic heavy metals in pork food products. Steps have to be taken to control the environmental contamination, as a primary and effective food safety measure. There is also an absolute need for good manufacturing practices and Hazard Analysis and Critical Control Points to monitor and curtail the contaminants in meat and meat products.

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