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A Comparative Evaluation of Some Heavy and Trace Elements in Canned Tuna and Processed Meat in the Egyptian Local Market

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ABSTRACT

In this study, some heavy metals and trace elements (iron, copper, zinc, lead, cadmium, and tin) were determined in selected canned tuna fish and processed meat products available on the local Egyptian market using atomic absorption spectroscopy (AAS). The results indicated that the Fe, Cu, Zn, Pb, Cd, and Sn levels in canned tuna ranged between 48.97–60.01, 1.81–4.5, 17.19–27.57, 1.51–1.82, 0.96–3.85, and 1.06–3.67 mg/kg, respectively. In the selected meat products (luncheon, beef burger, beef frankfurter, and oriental sausage), the levels of Fe, Cu, Zn, Pb, and Cd varied between 14.27–26.36, 1.31– 4.48, 9.53–19.59, 0.78–2.88, and 1.50–3.54 mg/kg, respectively. Statistical analysis of the canned tuna results indicated that Fe, Cu, and Cd were strongly related to the production date and, potentially, the catch date, while Pb and Zn were related to the can material and solder. Statistical analysis of meat products data indicated that different meat processing preparations and operations did impact the levels of the detected elements in the tested produce. As well, thermal processing, meat curing operations, and additives may have affected the mineral content of processed meat.

Keywords: Canned tuna, meat products, heavy and trace elements, statistical analysis.

1. Introduction

Fish, meat, and meat products are an essential part of the human diet in many parts of the world (Alturiqi and Albedair, 2012). Fish are rich in essential amino acids, micro, and macro elements (calcium, phosphorus, fluorine, and iodine) (Hussein and Khaled, 2014). They also contain liposoluble vitamins and provide omega-3(n-3) fatty acids that reduce cholesterol levels and incidences of heart disease, stroke, and preterm delivery (Hussein and Khaled, 2014). While they are widely consumed in many parts of the world, trace metals and non-essential elements from both natural sources and contaminated aquatic environments accumulate in fish tissues (Hussein and Khaled, 2014). Therefore, there is a potential risk of exposure to the chemical contaminants from not only fish but also processed fish products. Meat and its products are also considered a rich source of protein, fat, and phosphorus (Maky *et al.,* 2020). As well, meat is an excellent source of essential trace elements such as iron, zinc, selenium, vitamins A, B_{12}, and folic acid (Valaitienė *et al.,* 2015). However, with recent concern on the increase of heavy and trace metals ingested through foods due to anthropogenic activities, more regulations were instated to control their content in fresh and processed food products to limit their hazardous impact on human health.

From another perspective, elements such as iron, copper, zinc, and manganese, are considered essential elements as they have an important role in biological systems (Alturiqi and Albedair, 2012). Nonetheless, known essential metals can also produce toxic effects if they are ingested in large concentrations. Moreover, some elements such as cadmium and lead are considered toxic even in trace quantities. Cadmium has a neurotoxic effect and a destructive effect on the bone disturbing the

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metabolism of calcium and vitamin D as well as it may reduce the body's immune capacity (Kowalska *et al.,* 2020). Lead also causes numerous disorders and diseases such as damaging erythrocytes, weakening of bones, blocking the nervous system, inhibiting the absorption of iodine necessary for the correct functioning of the thyroid gland, and forming toxic deposits in the organism (Kowalska *et al.,* 2020). Furthermore, Cd and Pb disturb the metabolism and absorption of essential elements such as iron, copper, manganese, zinc, and selenium by the human organism (Kowalska *et al.,* 2020). Tin is relatively less toxic than cadmium, lead, and arsenic, however, high levels can cause gastric and intestinal irritation and disorders (Kowalska *et al.,* 2020).

Generally, the food industry employs a variety of manufacturing techniques to process, preserve, and extend the shelf life of food resources (Kowalska *et al.,* 2020). Of these techniques, canning is regarded as an optimal route that does not have any storage requirements during transport or distribution (Kowalska *et al.,* 2020). This has made canned foods (e.g. vegetables, fruits, meat, drinks, and fish) very popular nutritional sources all over the world, becoming an important source of carbohydrates, proteins, vitamins, minerals, and trace elements (Massadeh and Al-Massaedh, 2018).

However, canned containers have a high potential for releasing container metals into the food (Dallatu *et al.,* 2013). This may be due to the leaching of heavy metals from unlacquered cans or tin foil packaging through corrosion. Moreover, improper technological processing or incorrect packaging may add to this metallic burden (Kowalska *et al.,* 2020). For example, tin is used in the plating of metal containers that may be released into foods from defective cans or in the presence of an acidic medium (Kowalska *et al.,* 2020). In addition to environmental contamination sources, food processing activities such as canning and cooking may increase Ni in foodstuff (Ashraf *et al.,* 2006).

As well, some foods, such as processed meat manufacturing, require additives to maintain the favorable texture, color, flavor, and taste and prolong product life (Maky *et al.,* 2020). More specifically, nitrite is used in meat processing to maintain the red color and inhibit bacterial growth and fat rancidity. Phosphates are also added to processed meat as a pH stabilizing agent to improve water holding capacity and prolong product life.

However, with the increase in environmental and terrestrial contamination, these applied production processes may not be able to eliminate the presence of these elements within the foodstuff. Moreover, they may increase them within the processed products due to the applied operations (Ashraf *et al.,* 2006). This, optimally, causes these elements to bio-accumulate in human tissues leading to serious biohazards as they are not metabolized within the body.

Thus, with the growing concern about human exposure to metals due to processed foodstuff ingestion, the objective of this study is to determine the levels of some heavy and essential metals in selected canned tuna fish and processed meat products present on the local Egyptian market. The results obtained were compared with the analysis and production dates of the foodstuff as well as some major labeled ingredients. Through the application of statistical analysis of the obtained data, the impact of the processing operations of these foodstuffs, analysis date, and the potential source of these elements will be elucidated.

2. Materials and methods

2.1. Food samples selection

Canned tuna fish and four types of processed meat products (luncheon meat, beef burger, beef Frankfurter, and oriental sausage) were selected for this study. The samples were randomly collected from Egyptian local supermarkets. Before any analytical determination, information as to the type of package, weight of product analyzed, the food's labeled ingredients and dates of production as well as the respective date of analysis were recorded in Tables 1 and 2. Heavy and essential metals levels (Cu, Cd, Pb, Fe, Sn, and Zn) within each sample were determined either during the product's shelf life or after the product expiration date.

2.2. Sample preparation and extraction

For the tuna, the cans were opened and drained for 2 min through a sieve to remove brine and oil. The content of each can was then homogenized in a high-speed blender. For processed meat food, samples proceeded directly towards homogenization. Each sample was weighed and transferred into a weighed crucible and dried at 105 °C in an oven with assisted air circulation to remove all residual water before ashing. The vessels were then placed in a muffle furnace and gradually heated to 550 °C (at a rate of 50 °C /30 min) and ashed for 2 hr. (Ranasinghe *et al.,* 2018). The residue was dissolved in 10 mL of HNO_3 (10% v/v), and the mixture was heated slowly to dissolve the residue. The solution was then filtered through Whatman No. 42 filter paper and transferred into a 50 mL volumetric flask and made up to volume with distilled water.

The final solutions were analyzed for the selected elements (Cu, Cd, Pb, Fe, Sn, and Zn) using atomic absorption spectroscopy (Thermo Electron Corporation, S SERIES). Before measurement, the equipment was calibrated with standard solutions for the selected elements (Cu, Cd, Pb, Fe, Sn, and Zn) and each sample was analyzed in triplicates.

Table 1. Product details and labeled ingredients - the tested canned tuna.

Sample No.	Package type	Tuna weight/ can (g)	Production date	Analysis date	Labeled ingredients
1	Tin can	170	January 2020	March 2021	Meat tuna in non-GMO treated soya bean oil light and Brine.
2		200	February 2020		
3		170	March 2020		
4		150	May 2020		

Table 2. Product details and labeled ingredients and the selected meat products samples.

Sample type	Package type	Weight (g)	Production date	Analysis date	Labeled ingredients
Luncheon meat	Plastic water-proof casing	250	June 2021	June 2021	Frozen halal lean beef 30–35%, 20–24% fat, 30–35% water and ice, and 5–10% powdered additives including phosphates, ascorbate, soy protein, fillers such as starch and cereal binder, salt, spices, and sodium nitrite (max. 100 ppm).
Beef burger	Plastic package	1000	May 2021	June 2021	Frozen halal beef meat, carbohydrate, soy protein, salt, spices, phosphate, and sodium glutamate.
Beef Frankfurt	Plastic package	250	May 2021	June 2021	Frozen halal beef, water, corn syrup, 2% or less: salt, potassium lactate, hydrolyzed beef stock, natural flavor, phosphates, ascorbate, soy protein, extractives of paprika, and sodium nitrite (max. 80 ppm).
Oriental sausages	Plastic package	900	May 2021	June 2021	Frozen halal beef meat, carbohydrate, soy protein, salt, spices, phosphate, and sodium glutamate.

2.3. Chemicals and reagents

All chemicals used were of the highest analytical purity. All solutions (standards and reagents) were prepared using distilled water. Nitric acid (69.5%) was purchased from CARLO ERBA Reagents SAS (France). Heavy and essential metals' standard solutions (Cu, Cd, Pb, Fe, Sn, and Zn) were purchased from Merck (Germany).

2.4. Statistical analysis of Data

Statistical analysis of data was carried out using "StatistiXL 1.8" incorporated within the Microsoft Excel 2010 (Microsoft ® Windows 2010) software program. Cluster analysis was performed using the Pearson correlation method to measure the magnitude and statistical relationship, or association, between variables and the degree of the linear relationship between two continuous random variables based on the method of covariance.

3. Results and Discussion

Generally, it has been indicated that essential elements such as Fe, Zn, Cu, and Ni have an important physiological role in cellular homeostasis and survival and act as functional components and activators in various metalloenzymes (Alcala-Orozco *et al.,* 2021). However, there is a need to evaluate the exposure levels and their interrelationship with the type of processed food and technology used, which is an objective of this study.

3.1. Canned Tuna fish Samples: metals and trace elements content

Table 3 and Figure 1 show the results for (Cd, Cu, Fe, Zn, Pb, and Sn) in mg/kg within the four canned tuna fish samples, along with the date of production and respective analysis dates in days and months.

Table 3: Heavy and trace metal contents (mg/kg) in sampled canned tuna fish, the date of production (month/year) and the respective date of analysis (day/ month).

Date of production (M/Y)	Time of analysis (days/ months)	Elements determined (mg/kg)					
		Fe	Zn	Cu	Pb	Cd	Sn
Jan 2020	420/ 14	51.95 ± 0.46	25.73 ± 0.73	1.81 ± 0.05	1.74 ± 0.06	0.95± 0.07	2.76± 0.05
Feb 2020	390/13	53.05 ± 0.54	17.19 ± 0.19	2.74 ± 0.17	1.51± 0.19	1.89± 0.15	3.67± 0.14
March 2020	360/12	48.97 ± 0.12	19.78 ± 0.06	3.07 ± 0.15	1.70± 0.02	1.49± 0.04	1.06± 0.05
May 2020	300/ 10	60.01 ± 0.19	27.57 ± 0.08	4.50± 0.27	1.81 ± 0.04	3.84± 0.16	2.53± 0.04
Mean ± SD		53.5 ± 4.7	22.57 ± 4.9	3.03 ± 1.1	1.7 ± 0.1	2.04 ±1.3	2.5 ± 1.1

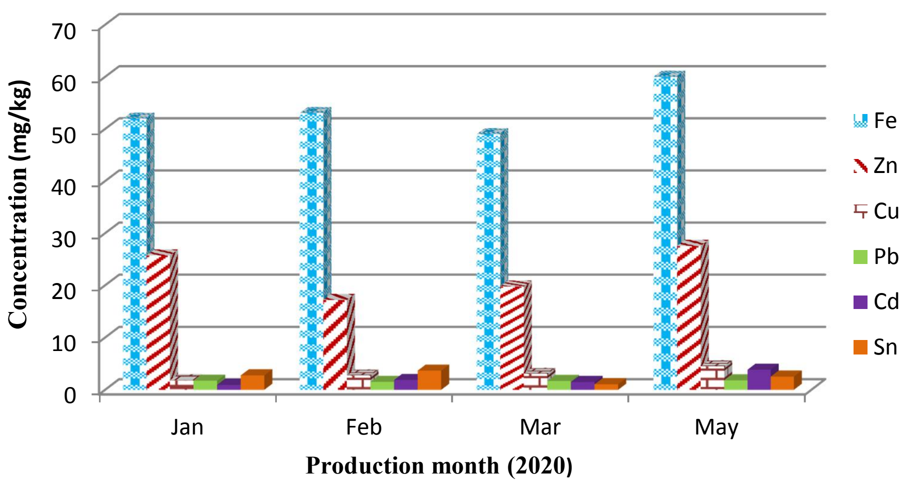

Fig. 1: Variation in Cd, Cu, Fe, Zn, Pb, and Sn content (mg/kg) per production month for canned tuna samples.

The data revealed that the highest levels of the studied elements- except for Sn, were found in canned tuna produced during May 2020. For the Fe content, the lowest level was found in the canned tuna produced during March while the highest was in May 2020. Ashraf *et al.* (2006) reported an average of 2.94 -6.80 mg Fe/g for canned tuna collected from the KSA market, which is below the current study values. However, in a more recent study, Al-Mutarri (2015) reported a Fe range of 57.41 to 101.55 ppm for canned tuna sold in KSA with the higher value attributed to the addition of tomato salsa. He also reported that there was no maximum limit set for Fe by the WHO, however, but the Ministry of Agriculture in the Republic of Turkey has proposed 15 mg/kg as a limit for canned tuna. Sobhanardakani (2018) reported that Fe levels ranged between 34.02-77.53 μg/g in canned tuna obtained locally in Tehran (Iran), which are similar to the current results. As well, Alcala-Orozco *et al.* (2021) reported a mean Fe of 43 mg/kg in canned tuna available at the Colombian markets. On the other hand, de Lima *et al.* (2021) studied the presence of trace elements in a variety of commercialized canned tuna available on the Brazilian markets. They reported that the highest Fe content of 3.3-3.9 mg/ 130 g was found in natural grated tuna while 1- 1.4 mg Fe/ 130 g was found in solid tuna in oil. Moreover, they indicated that the reported Fe content was in agreement with that found in a study of canned tuna in Iran (1.7 mg Fe/130 g) and another concerning Fe content within Mediterranean wild Atlantic Bluefin tuna (1.7 mg/130 g). However, they reported that FAO/WHO tolerable daily intake limit of Fe was 0.8 mg/kg/day, which is equivalent to 56 mg/day for 70 kg adults.

The lowest level of zinc in canned tuna was found in the February product. The East African Standards for Zn in tuna canned in oil was designated to be 50 ppm (Al-Mutarri, 2015). However, Ashraf *et al.* (2006) showed that Zn in canned tuna in KSA averaged between 3.80–17.70 µg/g, which is comparable with the current data. Al-Mutarri (2015) had a smaller range of zinc between 17.5 and 37.5 ppm for canned tuna found at El Hilla city in Iraq. The current results are within the similar range reported by Novakov *et al.* (2017) for Zn found in canned tuna in Serbia (3.16 - 44.50 mg/kg). Alcala-Orozco *et al.* (2021) reported a larger range of 20 – 141.6 mg Zn /kg in canned tuna available at the Colombian markets.

Cu content of the tested canned tuna ranged between the lowest levels in January 2020 and the highest in May 2020 (1.8–4.50 mg/kg, respectively). The current Cu content is below the maximum provided for this element by FAO of 30 mg/kg and the Saudi standards of 20 mg/kg (Al-Mutarri, 2015). Ashraf *et al.* (2006) reported a 0.13–1.87 µg/g range for Cu in some selected canned tuna in KSA during their study, which is comparable with the current data. Higher Cu content ranged (5.43 ppm - 6.48 ppm) was reported in canned tuna from Iraq during 2012- 2013 by Al-Mutarri (2015). The current Cu levels are in agreement with those obtained by Islam *et al.* (2010) of 0.63- 3.13 mg/kg for canned tuna in South Korea. Sobhanardakani (2018) also reported Cu levels in a comparable range of Zn (0.73–1.18 µg/g) for canned tuna bought in Tehran (Iran), which is closer to the lower value obtained in this study. Similarly, canned tuna investigated in Colombia had an average of 1.5 mg Cu/kg (Alcala-Orozco *et al.,* 2021).

High accumulation of lead was reported to be found in muscles (tissue) and organs (Ashraf *et al.,* 2006). In this study, the mean Pb content determined was 1.7 mg/kg. It is notable to see that the current Pb levels were higher than the maximum acceptable limits recommended by different authorities and agencies, such as the Committee for Inland Fisheries of Africa (CIFA) (1992) of 0.35 mg/kg in canned fish; FAO/WHO (1992) of 0.5 mg/kg in fish; and the European Commission (EC) (2001, 2006) of 0.2 and 0.3 mg/kg in canned fish, respectively. However, the current results are at the lower range limit determined by of 1.14-3.78 mg Pb /kg for canned products collected in Assuit, Egypt. Other studies reporting Pb levels in canned tuna/fish were: in KSA of 0.23–0.84 µg/g (Ashraf *et al.,* 2006); in Serbia 0.15 µg/g (Novakov *et al.,* 2017); in Iran 0.75 µg/g (Sobhanardakani, 2018); in Jordan 2.5-2.8 µg/g (Massadeh and Al-Massaedh, 2018), in Poland 0.068 mg/kg (Kowalska *et al.,* 2020) and Colombia of 0.015 µg/g (Alcala-Orozco *et al.,* 2021).

Sources of cadmium in foods are either of environmental or naturally occurring metal in local soil and water bodies (Ashraf *et al.,* 2006). The concentration of Cd in the tested fish was higher than the maximum acceptable limits recommended by FAO/WHO (1992) of 0.5 mg/kg in fish and by EC (2006) of 0.1 mg/kg. As well, WHO/FAO has determined a maximum tolerable weekly intake of 7 µg Cd/kg of body weight (Ashraf *et al.,* 2006). Sharkawy *et al.* (2020) reported that Cd concentrations in all examined canned tuna samples in Assuit City were between 0.47 and 0.79 mg/kg, which are lower than the current determined values. Ashraf *et al.* (2006) also determined the Cd content of canned tuna in Saudi Arabia to be between 0.07–0.64 µg/g.

The level of Sn in the canned tuna was highest in February product and the lowest was in March. The maximum level of Sn in food was proposed to be 250 mg/kg by the Ministry of Agriculture, the Republic of Turkey (2002), WHO (1996), and Associação Brasileira da Indústria de Alimentos (ABIA) (1998). However, a higher mean Sn content of 3.347 mg/kg in canned tuna was reported by Al Ghoul *et al.* (2020). Kowalska *et al.* (2020) determined the Sn content in canned tuna in Poland to be 0.018-1.36 mg/kg. Generally, tin cans are considered vulnerable to environmental injury and the element may leach to canned products via corrosion (Alcala-Orozco *et al.,* 2021).

Generally, Ashraf *et al.* (2006) indicated that the presence of Fe, Cu, Cd, and Zn in canned fish products may be a result of environmental pollution in the capture zones, cross-contamination during the canning process and/or the equipment employed during food processing. Tin is the main element used in packaging material, and external damage and corrosion may leach it into the can content. Contribution to Pb levels in fish may be due to the solder material used in can manufacturing as well as pollution of ocean ecosystems (Ashraf *et al.,* 2006; Russo *et al.,* 2013). Ashraf *et al.* (2006) indicated that a probable source contributing to Zn and Fe contents in these canned products may be the enamel of the cans in which fish was processed. However, the use of statistical analysis will help in elucidating the interrelationship between the measured parameters of this study.

3.2. Statistical Analysis of Canned Tuna Data

To better understand the correlations between the obtained variables, the data were statistically analyzed using the Pearson Correlation method. This statistical correlation measures the extent to which two variables fluctuate together through positive or negative correlations indicating the extent of increase or decrease of variables with each other. Pearson's correlation as well measures the degree of a linear relationship between two continuous random variables. Table 4 shows the Pearson similarity matrix between the data obtained for heavy metals in canned tuna fish, which is also depicted in Figure 2.

Table 4: Similarity Matrix (Pearson Correlation) Heavy and Trace Elements Determined in Canned Tuna with Production and Analysis Dates.

	Prod. date	Analysis date	Fe	Zn	Cu	Pb	Cd	Sn
Prod. date	1							
Analysis date	-1	1						
Fe	0.691833	-0.69183	1					
Zn	0.361569	-0.36157	0.623283	1				
Cu	**0.991876**	**-0.99188**	**0.728854**	0.301718	1			
Pb	0.484123	-0.48412	0.405	**0.900024**	0.38794	1		
Cd	**0.919992**	**-0.91999**	**0.905132**	0.429289	**0.948373**	0.37434	1	
Sn	-0.29292	0.292919	0.382118	-0.08181	-0.18545	-0.5052	0.094465	1

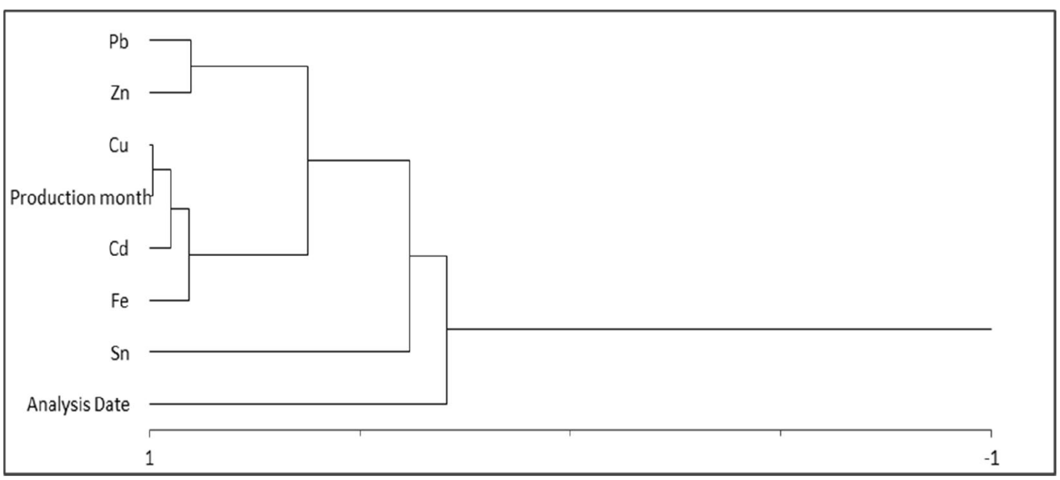

Fig. 2: Dendrogram depicting the relationship of heavy and trace elements with each other, production date, and analysis date in canned tuna using Pearson Correlation method.

There is a significant strong linear relationship between the date of production and the level of Cu in the tested fish. These two parameters were also strongly related to the measured Cd and Fe contents which may indicate their source to be environmental pollution and related to the date of catch rather than can corrosion. Pb and Zn were strongly related to each other. Essentially, Pb was reported to be used as the solder material in canned tuna manufacturing (Russo *et al.,* 2013). As well, it was reported that Zn due to its anti-microbial qualities was commonly used to line the inside of cans to prolong foods' shelf lives. Finally, all measured elements were related to Sn which is the material used in the can. Overall, these measured elements were negatively affected by the date of analysis (Cu > Cd> Fe>Pb> Zn) except for Sn, i.e., they may be more related to the date of catch and the production process.

3.3. Processed Meat Samples: Metals and Trace Elements Content

Meat and its products are a rich source of high biological protein, fat, iron, vitamins, and other fundamental elements (Maky *et al.,* 2020). However, contaminated animal feed and grazing of livestock in polluted terrain may contribute to heavy metal contamination of the meat (Hamasalim and Mohammed, 2013). In addition to that, heavy metal pollutants may contaminate products during processing either through raw materials, spices, water, and/ or packaging. Moreover, in meat processing food additives are extensively used to improve the texture, color, flavor, and taste as well as prolong its durability.

Table 5 and Figure 3 show the results of (Cd, Cu, Fe, Zn, and Pb) (mg/kg) content determined in the four selected meat products tested; namely: luncheon, beef burger, beef frankfurter, and oriental sausages.

Table 5. Heavy and trace metal contents (mg/kg) in sampled processed meat samples.

Product	Elements				
	Fe	Zn	Cu	Pb	Cd
Luncheon	26.36 ± 0.22	19.59 ± 0.40	4.48 ± 0.29	2.88 ± 0.20	3.54 ± 0.30
Beef burger	25.25 ± 0.38	13.08 ± 0.31	1.31 ± 0.02	0.78 ± 0.04	1.73 ± 0.12
Beef Frankfurters	14.27 ± 0.23	9.53 ± 0.29	3.29 ± 0.06	2.79 ± 0.23	1.97 ± 0.04
Oriental sausages	17.54 ± 0.30	10.95 ± 0.06	1.34 ± 0.03	1.82 ± 0.09	1.50 ± 0.04

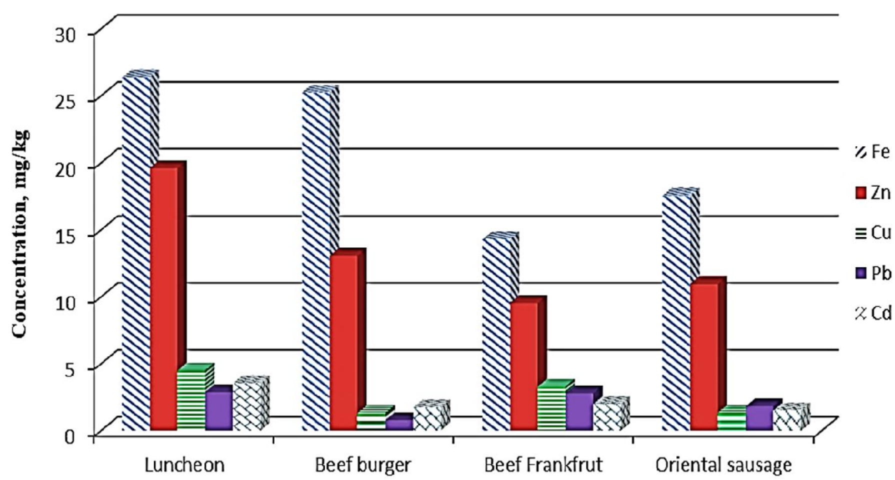

Fig. 3: Variation in Cd, Cu, Fe, Zn, Pb, and Sn content (mg/kg) per processed meat type.

It is worth mentioning that all processed meats have high iron and zinc content since meat is an excellent source of essential trace elements, such as iron, zinc, selenium, vitamins, and folic acid (Valaitienė *et al.,* 2015). Overall, both the luncheon and beef burger mixes had the highest Fe and Zn contents. The concentrations of Fe, Zn, Cu, Pb, and Cd in luncheon were 26.36, 19.59, 4.48, 2.88, and 3.54 mg/kg, respectively. This increase in Fe and Zn may be due to the use of actual frozen red meat. The obtained results are much lower than those reported by Alturiqi and Albedair (2012) for luncheon (mg/kg dry weight), which were 203.06 ± 11.61, 73.94 ± 3.10, 13.78 ± 0.70, 13.86 ± 0.94, and 4.08 ± 0.18 for Fe, Zn, Cu, Pb, and Cd, respectively.

In the case of the beef burger, Fe, Zn, Cu, Pb, and Cd levels were 25.25, 13.08, 1.31, 0.78, and 1.73 mg/kg, respectively. Alturiqi and Albedair (2012) reported that lean beef had 175.69 ± 6.97, 30.34 ± 1.39, 14.84 ± 0.40, 10.02 ± 0.59, and 3.06 ± 0.16 (μg/g dry weight) of Fe, Zn, Cu, Pb, and Cd, respectively. Those results are higher than those obtained in the current study, except for Cd. Overall, Manea *et al.* (2017) reported the following ranges in mg/kg for Fe (11.748–26.131), Zn (4.282–11.586), Cu (1.987–4.154), Pb (0.242–0.477) and Cd (0.091–0.095) in processed meat products in Romania, with which the current Fe, Cu, and Zn agree.

In the case of oriental sausages, Fe, Zn, Cu, Pb, and Cd concentrations were 17.54, 10.95, 1.34, 1.82, and 1.50 mg/kg, respectively. However, the obtained results are lower than those obtained by Alturiqi and Albedair (2012). They reported Fe, Zn, Cu, Pb, and Cd levels (µg/g dry weight) in sausages to be 242.44 ± 12.09, 65.43 ± 2.06, 18.51 ± 0.54, 15.43 ± 1.22, and 3.33 ± 0.17, respectively.

For the beef frankfurters, the concentrations of heavy metals were 14.27, 9.53, 3.29, 2.79, and 1.97 mg/kg for Fe, Zn, Cu, Pb, and Cd, respectively. Korish and Attia (2020) reported concentrations of Fe, Zn, Cu, Pb, and Cd of 72.8, 26.4, 7.80, 14.84, and 0.38 mg/kg, respectively. It can be noticed that, except for Cd, their results were higher than those obtained in the present study.

In this study, Cu content exceeded the maximum level (3 mg/kg) prescribed by FAO and EC in meat products (EC 178, 2002; FAO, 2002). On the other hand, the Central Agency for Standardization and Quality Control of Iraq (1988) regulated the Cu content in luncheon meat not exceeding 15 mg/kg (Hamasalim and Mohammed, 2013). The zinc content obtained in the current study was below the upper allowed limit of 50 mg/kg (FAO, 2002). Moreover, Hoha *et al.* (2014) reported that sausages had higher cadmium content than raw meat. This increase in Cd may be due to the addition of spices during the production of sausages as they may contain up to 200 ng Cd/g. As well, other sources of cadmium include anthropogenic contamination of food through water, air, and soil (Hamasalim and Mohammed, 2013). The Pb levels were relatively closer to those limits set for pork products as recommended by FAO (2002) and EC 1881 (2006) (1 mg/kg) in sausage. Sources of Pb contamination may be livestock feed such as water and food materials or during production from cooking utensils and food packaging used. In general, lead accumulates in plants and animals and its concentration is magnified in the food chain (Hoha *et al.,* 2014). As well, some spices used during the processing of meatballs, corned beef, burger's beef and sausages were reported to be one of the sources of lead pollution (Hamasalim and Mohammed, 2013).

3.4. Statistical Analysis Of processed meat Data

Initially, to understand the provided data, a hierarchal cluster analysis was performed using the obtained analytical data for the processed meat samples. Therefore, Pearson correlations will be drawn for each product to elucidate the source of the measured elements.

Table 6 shows the Pearson correlations between the data obtained for heavy and trace elements in the luncheon, which is also depicted in Figure 5.

Table 6: Pearson similarity matrix for the Fe, Zn, Cu, Pb and Cd determined in luncheon.

	Fe	Zn	Cu	Pb	Cd
Fe	1				
Zn	0.382175	1			
Cu	0.3137	-0.75756	1		
Pb	**0.757442**	**0.892816**	-0.38234	1	
Cd	0.237772	**0.988459**	**-0.8477**	**0.814276**	1

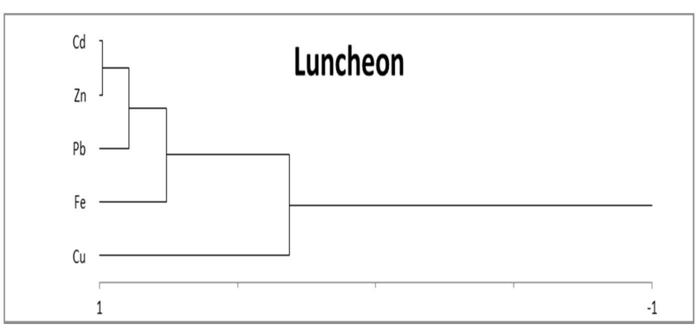

Fig. 5: Dendrogram depicting the relationship between heavy metals with each other in luncheon using the Pearson Correlation method.

From these results, it is clear that there is a significant and strong linear relationship between Zn and Cd, between Zn and Pb, and between Pb and Cd, all of which were correlated to the product

Fe content. This indicates that these elements were inherent to the raw materials used (raw meat, spices, and water). There was also a strong negative correlation between Cu and Cd and Cu and Zn and to a lesser degree; Cu and Pb. Polidori *et al.* (2021) indicated that while meat is the richest source of iron, zinc, and copper in a diet, cooking processes may reduce the meat content of the trace elements after thermal treatments.

Table 7 shows the Pearson correlation similarity matrix for the analytical data obtained for elements in beef burgers which are also depicted in Figure 6. From this figure, it is clear that there is a strong negative correlation between Fe with (Cu and Pb), Zn with (Pb and Cu), and Pb with Cd. However, Fe was positively correlated with Zn, which was attributed to red meat content (Polidori *et al.,* 2021). However, there is a strong positive correlation between Cu and Pb, and Zn with Cd, which may be attributed to the use of spices and other additives during the curing of red meat.

Table 7: Pearson similarity matrix for the measured heavy and trace elements in beef burgers.

	Fe	Zn	Cu	Pb	Cd
Fe	1				
Zn	0.521199	1			
Cu	**-0.99819**	-0.57162	1		
Pb	-0.62631	**-0.99175**	0.672094	1	
Cd	-0.0647	**0.817924**	0.004522	**-0.73742**	1

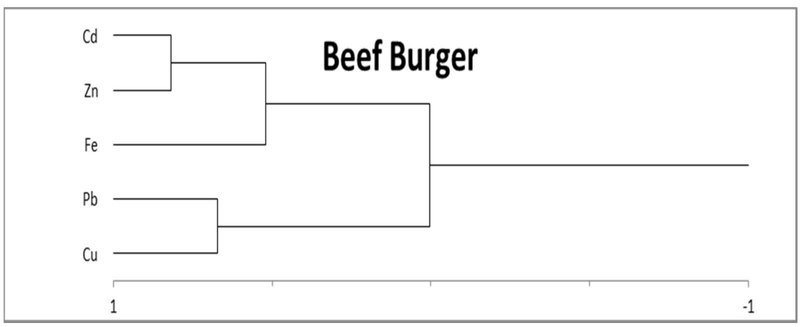

Fig. 6: Dendrogram depicting the relationship between heavy metals with each other in Beef burgers using the Pearson Correlation method.

Table 8 shows the similarity matrix for the data obtained for elements in oriental sausages which is also depicted in Figure 7. From the data, it is clear that there is a significant linear relationship between Zn and (Cu and Cd), Cu with Cd and Pb with Cd. This may reflect the use of binders (soy protein isolate), fillers (carbohydrates) and extenders (plant protein – soya beans) in the meat mix as well as spices blends during processing. However, the strong interrelationship between Fe and (Zn and Cu) may reflect the mineral content of the red meat as Fe was negatively related to Pb, which may be an additive with the spices mix.

Table 8: Pearson similarity matrix for the measured heavy and trace elements in oriental sausages.

	Fe	Zn	Cu	Pb	Cd
Fe	1				
Zn	0.650369	1			
Cu	0.69508	**0.998173**	1		
Pb	-0.4658	0.36924	0.31241	1	
Cd	0.020908	**0.77305**	**0.733307**	**0.874959**	1

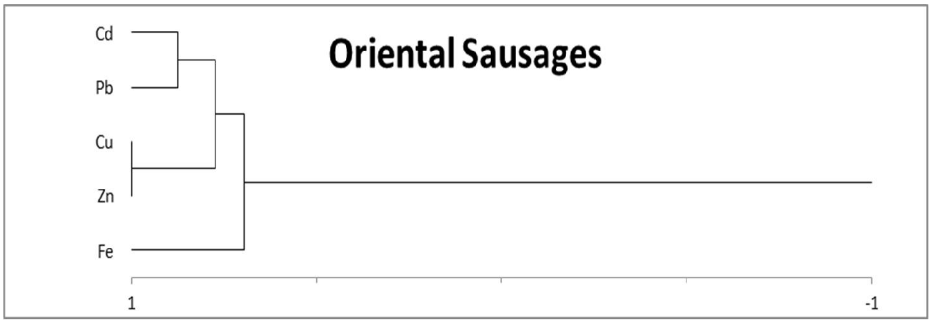

Fig. 7: Dendrogram depicts the relationship between heavy metals with each other in oriental sausages using the Pearson Correlation method.

Finally, Table 9 and Figure 8 show the correlation similarity matrix for the data obtained for beef frankfurters. From this data, it is clear that there is a negative correlation between Fe and Cu, Cd and Zn contents, which may be a result of minerals lost during thermal processing. However, there is a strong positive correlation between Cu and Cd. A negative correlation between Pb and Cu and Cd indicates that the source of the former element was not the same as the latter as well as its increase decreased the other trace element content during meat processing.

Table 9. Pearson similarity matrix for the measured heavy and trace elements in beef frankfurters.

	Fe	**Zn**	**Cu**	**Pb**	**Cd**
Fe	1				
Zn	-0.37536	1			
Cu	**0.88657**	-0.09598	1		
Pb	**0.703129**	0.395138	**-0.95231**	1	
Cd	**-0.88488**	-0.09962	**0.999993**	**-0.95341**	1

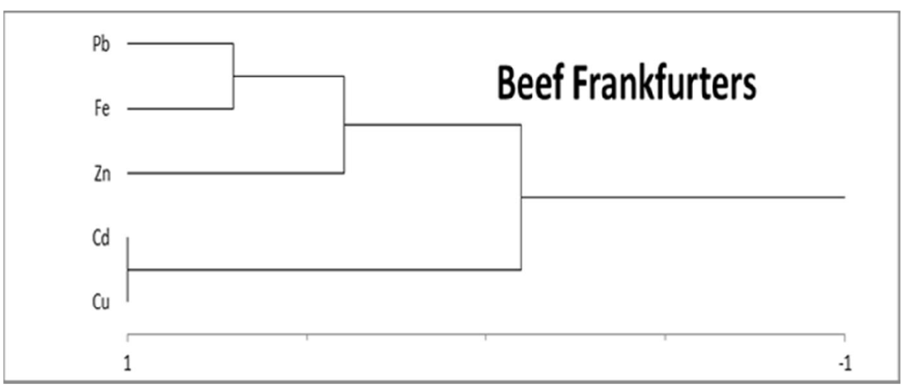

Fig. 8: Dendrogram depicting the relationship between heavy metals with each other in beef frankfurters using Pearson Correlation method.

4. Conclusion

In this study, heavy and trace elements were investigated in canned tuna and some selected processed meat products available on the Egyptian market. The results indicated that the Fe, Cu, Zn, Pb, Cd, and Sn levels in canned tuna ranged between 48.97–60.01, 1.81–4.5, 17.19–27.57, 1.51–1.82, 0.96–3.85, and 1.06–3.67 mg/kg, respectively. Also, the levels of lead, cadmium, and iron exceeded the recommended maximum acceptable levels in canned tuna. Statistical analysis of the canned tuna results indicated that Fe, Cu, and Cd were strongly related to the production and, potentially, the catch date, while Pb and Zn were related to the can material and solder.

For the selected meat products (luncheon, beef burger, beef frankfurter, and oriental sausage), the levels of Fe, Cu, Zn, Pb, and Cd varied between 14.27–26.36, 1.31–4.48, 9.53–19.59, 0.78–2.88, and 1.50–3.54 mg/kg, respectively. The increase in Fe and Zn in these products may be due to the use of frozen red meat. Statistical analysis of these data indicated that different meat processing preparations and operations did impact the levels of the detected elements in the tested produce. As well, thermal processing, meat curing operations, and additives may have affected the mineral content of processed meat.

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