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Full Length Research Paper

Detection of heavy metals bio-accumulation in scombrids for the determination of possible health hazard

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ABSTRACT

Concentrations of trace elements zinc, copper, nickel, chromium and heavy metals lead, mercury, cadmium and arsenic were detected in the muscle tissues of four commercially edible fishes belonging to the scombridae and related families including yellow fin tuna (*Thunnus albacares*), Dogtooth tuna (*Gymnosarda unicolor*), Marlin (*Makaira mazara)* and the dolphin fish (*Coryphaena hippuru)* in the EEZ (Exclusive Economic Zone) of Mauritius. The concentrations were within the range 1.34-10.03, 0.0-1.42, 0.23-0.89, 0.0-2.43, 0.0, 3.60-5.44, 0.03-0.13 and 0.03-0.07 mg/kg wet weight respectively for summer and winter seasons. Inter-species variations with respect to elemental accumulations were not significantly different as compared to seasonal variations for the accumulation of chromium, zinc and lead. Marlin and Dorado caught during the summer season exceeded the authorised level of chromium in muscle tissues according to international standards. A survey carried out among fish consumers in Mauritius revealed that 80 % of the respondents were ignorant about heavy metal bio-accumulation.

Keywords : Mauritius, muscle tissues, heavy metals, yellow fin tuna, Dogtooth tuna, Marlin, Dorado

INTRODUCTION

Heavy metals pollution in the marine ecosystems is a result of anthropogenic activities such as mining, shipping, agriculture and domestics (Haynes & Johnson, 2000; Islam & Tanaka, 2004). Humans as well as aquatic organisms are under the threat of a rise in heavy metals concentration in the marine environment (Uluturhan *et al*., 2007; Naji *et al.,* 2010; Bashir *et al.,* 2013). In the last few decades, fishes have been the subject of various studies around the world due to their ability to bio-accumulate heavy metals (Elnabris *et al.,* 2013). In an attempt to reduce possible human health hazards, commercially edible fish species are favoured for studies since the diet is the main route of human exposure to heavy metals (Türkmen *et al.,* 2005; Tepe *et al.,* 2008; Raja *et al.,* 2009; Alina *et al.,* 2011; Kumar *et al.,* 2012).

Heavy metals that are classified as harmful toxic substances are mercury, arsenic, lead and Cadmium among others. Mercury is considered as one of the most dangerous toxic heavy metal that can have adverse effects on human health. Lead and arsenic affects the reproductive system of women, by displaying toxicity towards the growing foetus (Goeringa *et al.,* 2010) while cadmium builds up in the placenta (Berlin *et al.,* 1992; Moberg *et al.,* 1992; Jarup *et al.,* 1998). Trace elements such as Zinc, Copper, Nickel and Chromium are present in low amount and are important in the human body system (Fraga *et al.,* 2005). However, if present in excess, they acquire toxic properties depending on the absorption, concentration and persistence at their action points (Shanker, 2008)

In the island of Mauritius with an Exclusive Economic Zone (EEZ) of around 1.9 million km, the previous Minister of Fisheries, Nicolas Von-Mally predicted a bloom in the Seafood Hub with investments ranging from Rs 30 billion to Rs 40 million (Business Mega, 2014). Local sea food consumption in Mauritius per capita is estimated to be around 20 kg (Business Mega, 2012). The Scombridea is a family of epipelagic marine fishes comprising of the mackerels, tunas and bonitos. Scombrids are active predators which are found at the highest tropic level of the aquatic food chains (Colette *et al.,* 1983).FADs (Fish Aggregating Devices) in Mauritius catch around 288 tons of scombrids annually where *albacares* tuna is most frequently caught.

These fishes of the Scombridae and related families possess bioaccumulation capacities as they are at the top of the trophic levels of the aquatic food chains (Kojadinovic *et al.,* 2006) and are important commercially edible fishes. These criteria make the fish species belonging to the scombridae and related families the best candidates for the detection of the levels of heavy metals in their muscle tissues which can thus can be used to ensure food supply safety and diminish any potential risk of health hazard for the population.

International government agencies such as the JEFCA (The Joint FAO/WHO Expert Committee on Food Additives), the World Health Organisation (WHO), the MAFF (Ministry of Agriculture, Fisheries, and Food) and the Mauritian Food act 1998 have proposed MPL (Maximun permissible level) of trace elements in the human diet as safety regulations and to be used as comparison standards.

The aim of this research is based on the detection of the levels of trace elements such as Zn, Cu, Cr, Ni and heavy metals such as Hg, Cd, Pb, As using AAS (Atomic Absorption Spectrophotometer) techniques in muscle tissues of four commercially edible fish species belonging to the scombridae and related family namely the yellowfin tuna (*Thunnus albacares*), Dogtooth tuna (*Gymnosarda unicolor*), Marlin (*Makaira mazara)* and the dolphin fish (*Coryphaena hippuru)* during the summer and winter seasons to assess their potential health hazard for the Mauritian population.

MATERIAL AND METHODS

Sample Collection

Fresh samples were collected from local markets and coastal fish landing stations, after careful identification based on morphological key characteristics (Table 1.0). three Ventral slices from different fishes of the same species were sectioned and sealed in polyethene bags. The fish samples were approximately of the same ventral diameter, ranging from 19 to 21 cm width. The samples were then placed in an ice bag and bought to laboratory. The sampling procedures were repeated several times in the different locations to obtain three replicates of each fish species for both winter and summer seasons.

Sample processing (Dry ashing procedure)

All glasswares and equipment were soaked in 10 % nitric acid overnight, rinsed with deionised water and dried in a drying cabinet prior use. A freeze dryer was run overnight to dry the fish muscles. The samples were then placed in acid washed jars, tightly sealed with paraffin and placed in a desiccator to prevent absorption of moisture.

The dried samples were crushed into powder by using motor and pestle. 2 grams of each sample were then placed in a 25ml crucible .This process was duplicated so that each fish sample obtained a replicate and placed into a muffle furnace at 500 °C for approximately 8 to 10 hours .After the samples have been ashed, 2 ml of concentrated nitric acid were placed in each crucible and cautiously swirled. Following this, the samples were placed in a sand bath at 68 °C. The samples which were then placed back into the muffle furnace at 500 °C for another 2 hours. Once the crucibles were cooled at room temperature, 10 ml of IM HCl were added in each crucible, swirled and made up to the mark in a 25ml volumetric flask.

Metal detection

Levels of the different heavy metals (Zn, Cu, Ni, Hg, As, Pb, Cd, Cr) were measured using the AAS. Each metals was detected at a specific wavelength and using a specific lamp. For the metals Zn, Cu, Ni, and Cr the apparatus was calibrated as those metals are normally detected through flame atomic absorption spectroscopy in parts per millions (ppm). Cd, Pb and As were detected using the graphite atomic absorption spectrophotometer, where the results were indicated in parts per billions (ppb) while Hg was detected using flameless AAS also known as AAS hydride in ppb.

Population survey

To determine population awareness about the implications of heavy metals in fish as well as their consumption patterns, a mini survey was conducted. The sampling frame used was the stratified sampling with 10 participants from each central local market. The questionnaires were distributed near the fish stall section. The questions were processed and analysed using the SPSS 20.0 software.

RESULTS & DISCUSSION

Cadmium was not detected in any fish samples and there is no significant difference between the bioaccumulation of all the detected trace elements with respect to the species (Table 2). Different fish species did not accumulate significantly different amount of trace elements in their muscle tissues ($P<0.05$). The levels of zinc, chromium and lead accumulated in muscle tissues of the four fish species are significantly different for the summer and winter seasons ($p <0.05$) while no significant difference in the accumulation patterns was

Table 1. Identification features of the four different fish species

Species	Skin colour	Flesh type	General morphology
1. Yellow fin Tuna	Metallic grey; yellow and silver on belly area	Reddish brown	Largest near middle of first dorsal base
2. Dogtooth tuna	Silver or white flanks and belly	White and scale less	Short pectoral fins and big heads
3. Dolphin fish	Pectoral fins are iridescent blue. The flank is broad and golden	White	Entire bodies are compressed and comprises of single dorsal fins extending from the head to the tail(Dianne, 2011)
4. Marlin	Metallic grey	Pinkish	Short dagger like structure at front

T**able 2.** Two Way ANOVA (p value) for the different trace elements

	Significant difference (p value)		
Trace element	**Species**	**Seasons**	**Seasons & Species**
Zinc	0.515	0.00	0.968
Copper	0.238	0.906	0.436
Nickel	0.376	0.758	0.192
Chromium	0.101	0.022	0.112
Cadmium*	-	-	-
Lead	0.922	0.00	0.922
Arsenic	0.254	0.426	0.535
Mercury	0.309	0.217	0.390

*Not detected

found for the accumulation of copper, nickel, arsenic and mercury ($p>0.05$). With respect to the inter-variations between the seasons and the different fish species, no significant differences were obtained ($p>0.05$).

Most of the respondents were female and all the respondents agreed that they consumed these four fish species regularly. With reference to figure 4, the percentage of respondents who correctly answered the question about heavy metals is 20 % while 80 % of the respondents wrongly answered this question and therefore do not know what are heavy metals.

Optimisation of digestion protocol and analytical techniques

The dry ashing procedure was used in this study whereby instead of repetitive oven drying at 135°C for 2 hours, freeze drying was used. Wet digestion was avoided due to the risk of reagent contamination, the constant attention requirement and the handling of corrosive acids (Elmer-Parkin Corporation, 1996). The advantages of using a freeze dryer as compared to oven drying include the preservation of the muscle tissue in its original form which can easily be grounded. Charring (partial blackening and burnt surfaces) of samples is also avoided as well as potential loss of metals due to volatilisation during heat application.

The FAAS has detection limits in the range of ppm and high ppb. The levels of Zinc, Copper, Chromium, Nickel, Cadmium and in several papers, lead, were reported in ppm levels. Igwemmar *et al*. (2013) obtained levels of zinc in four fishes in the range of 1-3 ppm, levels of copper ranging from 0.00 to 0.3 ppm and levels of lead not detected in ppm in Gwagwalada market, Abuja. Emeka *et al.* (2014) observed levels of Nickel in fish species to be in the range of 0.00 to 0.30 ppm, levels of chromium ranging from 0 to 0.5 ppm, levels of cadmium in the range of 0 to 2 ppm and 0 ppm for the detection of mercury in Oguta lake, Nigeria. Levels of Zinc, Copper, Nickel, Chromium and lead (fishes sampled in summer) were successfully detected using the FLAAS.

Hg and As were detected using the hydride system after unsuccessful attempts using the FAAS due to the low sensitivity of the FAAS and its detection limits not extending to low ppb. In the FLAAS, only a small portion of the sample is flown through the capillary cell and quickly into the flame. The hydride cell on the other hand, atomises a larger amount of the sample and retain the atomised sample for a greater time span, thereby enhancing the sensitivity of the technique (Parkin Elmer Coorporation, 2013). Arsenic, on the other hand, is thermally decomposed by the application of flames on the hydride cell, reducing arsenic (III) hydride into a gaseous hydride $AsH3$ by reaction with sodium borohydride in a hydrochloric acid medium (Behari *et al.,* 2006)

Melek *et al., (*2006) successfully determined the levels of cadmium (0.09-0.35 mg/kg dry weight) and lead(0.2-0.85) in fish samples using the GFAAS. This finding does not tally with this research whereby lead and

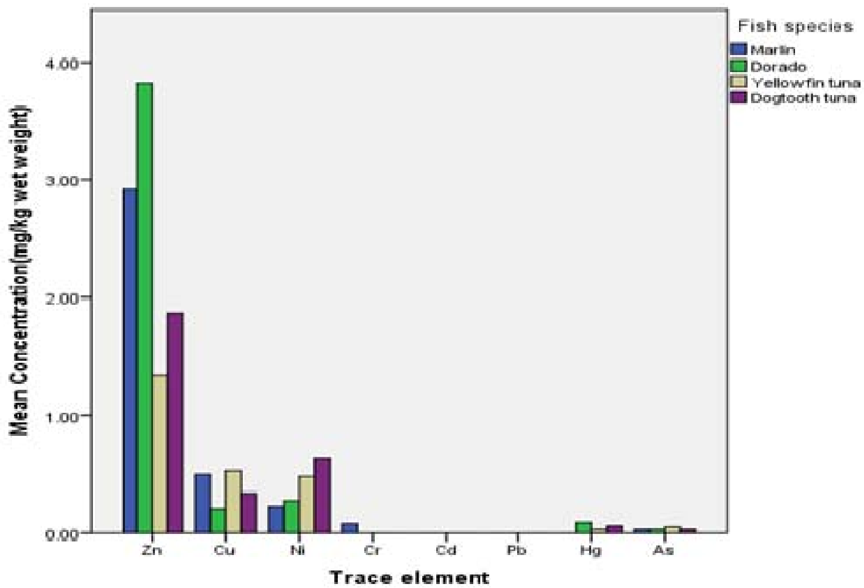

Figure 1. Mean concentration of different trace elements in fish muscles of different fish species for the winter season.

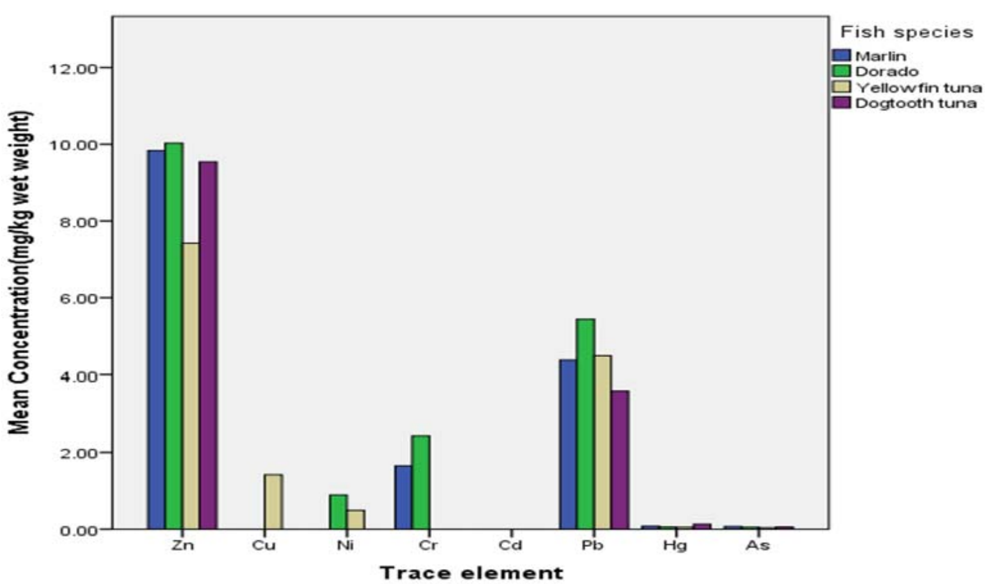

Figure 2. Mean concentration of different trace elements in fish muscles of different fish species for the summer season.

cadmium levels were not detected. This may be due to the use of phosphoric acid as the modifier which affected the analytical results as proposed by Melek *et al.,*(2006) who stated that the determination of trace elements in fish samples using the GFAAS is difficult due to the interference of a complicated matrix.

Inter-species comparison within elements

Elemental bioaccumulation in fish is related to two major factors, water through the gills and most importantly food (Dallinger *et al.,* 1987; Reinfelder *et al.,*1998; Smith *et al.,* 2002). The bloodstream is the main carrier of metals that circulate and deposit in various tissues. Unfortunately, the tropical zone of the Indian Ocean has not been the focus of researchers in terms of investigating the levels of trace elements in marine organisms (Kureishy *et al.,* 1979; Matthews, 1983; Mwashote, 2003; Robinson and Shroff, 2004 ; Kojadinovic *et al.,* 2006).

The concentrations of the trace elements Zn,Cu,Ni,Cr,Cd,Pb,Hg and As are not dependant on the fish species, that is fish species have no significant effect over the accumulation and uptake of the trace elements

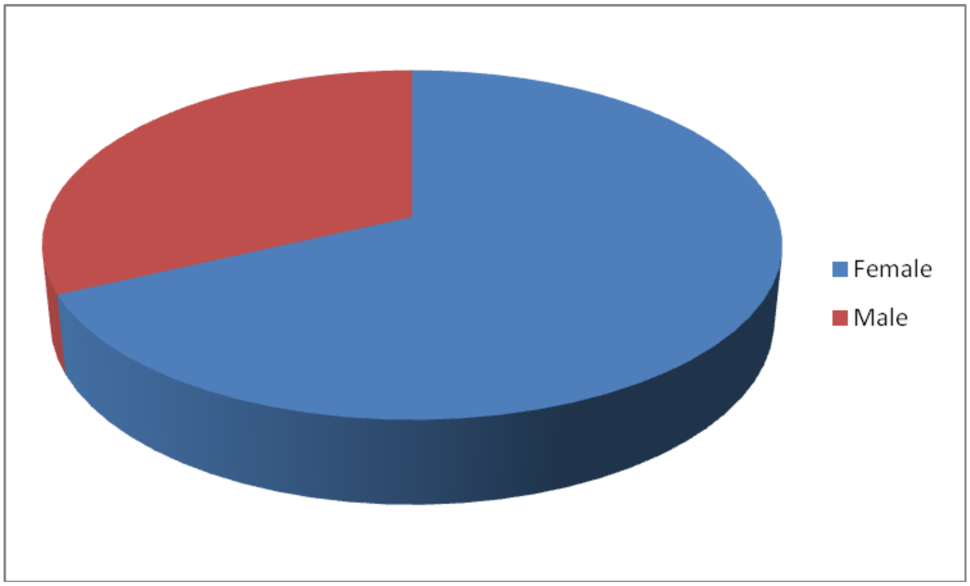

Figure 3. Pie chart illustrating the percentage of male and female respondents filling out the survey form. 68 % of fish buyers were female compared to 32% of males.

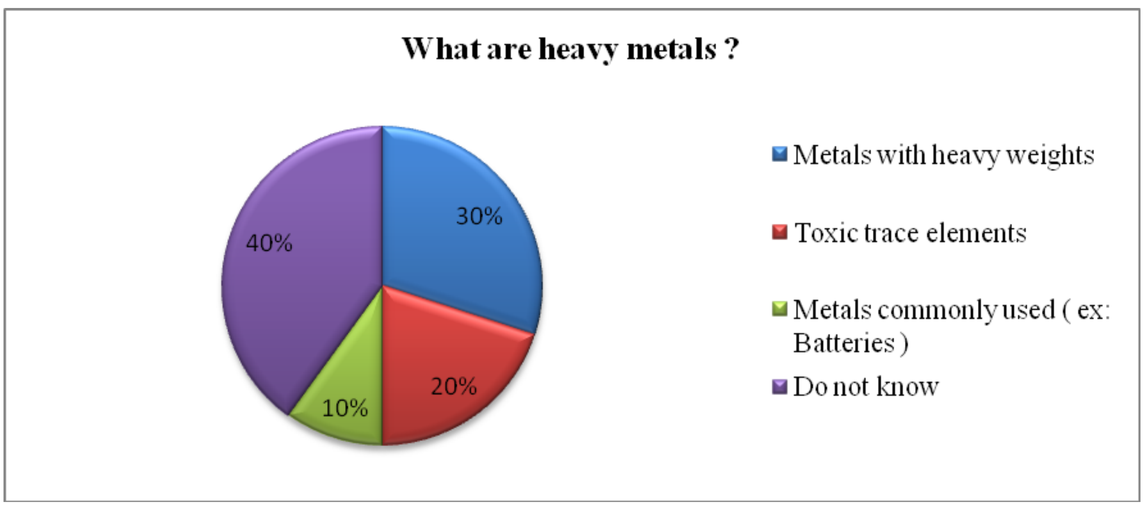

Figure 4 . Pie chart representing the number of respondents choice on the definition of heavy metals

in the muscle tissues of the fishes. These findings do not tally with kalay *et al.,*(1999) whose research revealed that metals accumulate in muscle tissues of different fish species in significantly different amounts. Moreover, Canli & Atli (2003) also supported the fact that levels of heavy metals vary in fish species and distinctive aquatic environments.

The difference between this study and the researches mentioned above could be explained by the organisms' size and aquatic environment as proposed by Jalal *et al*., (2014) who reported a relation between concentration of metal uptake and factors such as fish age, aquatic environment and size. The four fish species in this study were caught in the EEZ of Mauritius, at Riviere Noire fishing point and thereby may live in the same aquatic environment. Furthermore, the fishes caught were approximately of the same size, sampled by preferences of consumers and size availability. This accounts for the homogeneity of the levels of trace elements bio-accumulated in the four species. However, further research need to be conducted to confirm this trend as the sample size used for this study was small (n=3)

The levels of zinc (p=0.00), chromium (p=0.02) and lead (p=0.00) accumulated in muscle tissues of the four fish species are significantly different for the summer and winter seasons. The highest levels of the metals are accumulated during the summer season. One possible explanation to these findings is that an increase in the water temperature during summer increases heavy metals uptake in the fishes as compared to the winter season. Ahmed *et al.,* (2013) supported this claim by stating that seasonal variations with regards to the concentration of heavy metals bio-accumulated in fish species follow a trend whereby the highest levels of heavy metals are accumulated during summer while the lowest values are accumulated during winter due to a rise in temperature which favours the uptake of certain heavy metals.The higher water temperature during the summer season as opposed to the lower temperatures during winter, favours a rise in the accumulation uptake and binding of metals probably due to higher metabolic rate in the fishes as proposed by Jezierska *et al*., (2009). Obasohan & Eguavoen (2008) also suggested that the rate of pollutant accumulation is favoured during high temperatures as the blood's oxygen affinity is decreased. Khaled(2004) and Ali & Abdel (2005) observed a rise in metal concentrations during the warmer months in the tissues of some fish species as well as invertebrates and related this phenomenon to an increase in the organisms' metabolisms due to the higher temperature in summer.

Another possible factor responsible for the differences in accumulation across seasons is the migratory patterns of the four fishes. Beamish *et al.,* (2005) stated that pelagic fish species are highly migratory and the four fish species in this study are pelagic ones. Although present in most oceans, these pelagic fishes constantly migrate especially during the spawning season to warmer waters. Marlins are solitary and highly migratory fishes that are usually found in waters with surface temperatures of 21-33°C and yet spend the majority of its lifespan in warm near-surface waters from 25-27°C (Tung, 2003). The spawning season for the dolphin occurs mainly in waters above 24° C (Potthoff 1971; Palko *et al.*1982; Farell *et al.,* 2009). Tuna species mature and spawn around the year depending on regions although peak spawning season occurs during August-March (summer season in Mauritius) as suggested by Jones(1963).

Those four pelagic fishes migrate to warmer waters due to natural preferences or during sprawning season and this could explain the differential accumulation of heavy metals for the two seasons. Fishes caught in winter and summer may therefore come from different marine environments and be subjected to different conditions. Jezierska *et al.* (2009) suggested that accumulation is dependent on metal concentration, exposure time, route of metal uptake and environmental conditions such as water temperature, pH, salinity and feeding habits. The fishes caught during both seasons may belong to different schools of fish, come from different marine environments and have distinctive conditions proposed by Jezierska *et al*.,(2009) which would explain the differences in accumulation patterns.

Health-risk assessment for fish consumption

Safety regulations/guidelines of a country set the MPL (Maximum permissible level) of elements present in foodstuffs. In Mauritius, the Food Act 1998, implemented in 2000 sets regulations levels for the presence of heavy metals in foodstuffs such as seafood and fish. Local threshold guidelines can also be compared to international agencies such as WHO (The World Health Organisation) which is an international agency of the United Nations specialised in public health concerns. Other governmental agencies such as the JEFCA (The Joint FAO/WHO Expert Committee on Food Additives), the EC (European Comission), the MAFF (Ministry of Agriculture, Fisheries, and Food) in Britain have set MPL (Maximun permissible level) of trace elements in the human diet as safety regulations. Each agency has threshold levels for a series of elements, both complementary and distinct from the other legislation acts.

In Mauritius, the food act 1998 specifies a tolerable level of zinc at 100 ppm (100 mg/l). The concentrations of zinc detected in the four fish species lie in the range of 0.1 to 8 mg/l . Therefore, according to Mauritian standards, the tolerable level of zinc in fishes is respected, with observed values being far from the threshold level. Furthermore, the recommended MPL (Maximum Permissible level) for zinc is set at 50 mg/kg fresh weight in certain countries (MAFF,1995). The highest level of zinc obtained in this study is 10 mg per kg fresh weight (Table 3.1), which is five times inferior to the threshold levels set internationally. It can therefore be concluded that level of zinc in the four fish species are well below the maximum level indicated both in the Food Act 1998 and MAFF 1995.

Copper is a trace element responsible for the development of bones in the body but can have adverse effects if present in high concentrations (Fraga *et al.,* 2005). The Food Act 1998 specifies a tolerable level of copper at 30 ppm (mg/l). The concentrations of copper detected in the four fish species range from 0 to 4 mg/l(Figure 3.3) which is well below the threshold of the Food Act 1998. In addition, the MPL for copper in other countries is set at 20 mg/kg wet weight(MAFF,1995). The concentrations obtained for the analysis of the four fish species in this research lie between 0.2 to 1.4 mg/kg wet weight which is well below the threshold level set. Therefore, copper levels in the four fish species do not go beyond the local and international threshold levels.

Nickel is present in minute amounts in food, water, soil and air since it is a natural element of the earth's crust (EPA, 1989). There is no MPL set for Nickel in the Food Act 1998 but according to the WHO (1989), the MPL for nickel ranges from 0.5 to 1.0 mg/kg wet weight in fish muscles. The concentrations of nickel detected in the four fish species range from 0.2 to 0.9 mg/kg wet weight (Table 3.5). Dorado caught during summer have nickel concentration in its muscle tissues (0.89 mg/kg wet weight) close to 1.0 mg/kg wet weight but still lie within the permissible level. Therefore, the concentrations of nickel in all the four fish species lie within the range set by the World Health Organisation.

Chromium is excluded from the Food Act 1998 but according to FAO (1983), the MPL for chromium in fish is 1.0 mg/kg. Marlin (1.7 mg/kg wet weight) and Dorado (2.5 mg/kg wet weight) caught during the summer season exceed the authorised level of chromium in muscle tissues according to international standards. However, chromium has several oxidation states, primarily as metallic trivalent, which is found in most foods and nutrient supplements with very low toxicity (Cefalu *et al.,* 2004). The source of chromium in this research is not in the water since chromium originating from contaminated water builds up in the gills rather than in other fish tissues (Sneddon, 2013). Therefore one probable cause of chromium uptake in Dorado and Marlin is in their feeds.

The WHO(1989) has set the threshold levels for cadmium at 1.0 mg/kg wet weight and the Food Act 1998 specified permissible cadmium levels of 1.0 ppm. Levels of cadmium were not detected in any samples in ppm levels and therefore the levels of cadmium in the four fish species do not represent a health issue according to Mauritian standards.

The Food Act 1998 specifies a tolerable level of lead of 2.0 ppm (mg/l) in fish. The concentration of lead accumulated in the four fish species during the summer season lies in the range of 0 to 2.0 ppm. Some values are very close to the maximum permissible level indicated in the Food Act 1998 and should be closely monitored. Furthermore, WHO(1989) set the threshold level for lead at 2.0 mg/kg wet weight and all the four species caught during the summer season have lead concentration beyond the threshold level set (3.60-5.44 mg/kg wet weight). Close monitoring of the level of lead in muscle tissues of the four fish species during the summer season should be implemented with a greater number of fish samples to confirm the trend set in this study.

The Food Act 1998 set the acceptable threshold level of mercury in fish tissues at 1.0 ppm(mg/l). The level of mercury in the four fish species were detected at ppb level and then converted to ppm. The levels of mercury detected in the four fish species lie in the range of 0.02 to 0.71 ppm and therefore do not transgress the Mauritian threshold level. In predatory fish, the most wildly established guideline for mercrury is 1.0 mg/kg wet weight (IPCS, 1987; EPA, 1994). Fishes caught in the EEZ of Mauritius have levels of mercury in their tissues in the range of 0.03 to 0.1 mg/kg wet weight which is well below the threshold level set internationally. Thus the four fish species have threshold levels of mercury within the limits set locally and internationally.

The Food Act 1998 specifies level of arsenic at 1.0 ppm (mg/l). The level of arsenic in the four fish species were detected at ppb level and then converted to ppm. The level of arsenic accumulated in the four fish species ranges from 0.002 to 0.03 ppm which is far from the threshold level established and therefore do not transgress the Mauritian threshold level. Furthermore, the Joint FAO/WHO Expert Committee (1983) has also set a limit of 0.1mg per kg wet weight. The level of arsenic in the fish species ranges from 0.03 to 0.07 mg/kg wet weight and do not go beyond the international maximum permissible limit. The low levels of arsenic detected can be explained by a limited ability for Arsenic uptake. This hypothesis is supported by Gailer *et al.* (1995), Lansgton (1984) and Neff (1997) who observed that organisms belonging to the highest trophic levels like predatory fishes have a limited capacity to accumulate arsenic from the water columns as opposed to organisms at the bottom of the food chain such as bacteria, macroalgae and plankton.

Survey analysis (Awareness of heavy metal bioaccumulation)

The percentage of female fish buyers represent 68 % of the total respondents. This demonstrates that women are the main fish buyers at local markets. Women are also more vulnerable in the event of heavy metal accumulation in the body since some of the heavy metals such as arsenic, lead, mercury and copper affect the reproductive system of women, more specifically displaying toxicity towards growing foetus (Goeringa *et al.,* 2010). Therefore women, especially during pregnancy are at a greater risk but at the same time, they have the opportunity to determine which fish to buy. They should favour juvenile fishes which accumulates heavy metals to a lesser amount as compared to bigger predatory fishes.

Mauritians are thus good fish consumers and in the case of bio accumulation of heavy metals, this could pose a serious threat if the fishes were to transgress the maximum permissible levels such as lead and chromium in the diet. All respondents replied that they consume dorado, tuna and/or Marlin. This confirms that the fishes sampled in this study are commercially important fishes that are consumed by the general population. Therefore, the fishes selection was the most appropriate and targeted consumers at large.

With reference to figure 4, the percentage of respondents who correctly answered the question about heavy metals is 20 %. The remaining 80 % of the population are not aware of heavy metals at all. This is a serious concern since 82 % of the population affirmed that if according to health studies, the fishes mentioned above could be potentially harmful to their health, they would still consume them. The data shows that the population at large isn’t aware of the implications and gravity of the accumulation of heavy metals in fish which is a possible reason why they seem unconcerned about the possible health effects during fish consumption. If made aware, then perhaps peoples' opinions would change and they would become more health conscious. Proper sensitisation campaigns are a good stepping stone in aiding the population's awareness of the implications of heavy metals in the body.

CONCLUSION AND RECOMMENDATIONS

In this present study, the level of trace elements (Zn,Cu,Ni,Cr) and heavy metals (Pb,Hg,Cd,As) were analysed in the muscle tissues of four commercially important fish species. Inter-species variations with respect to elemental accumulations were not significantly different while seasonal variations for the accumulation of Cr, Zn and Pb were significantly different and attributed to the migratory nature of the fishes as well as a rise in the water temperature during summer which results in high metabolic rate and metal uptake. Marlin (1.7 mg/kg wet weight) and Dorado (2.5 mg/kg wet weight) caught during the summer season exceed the authorised level of chromium in muscle tissues according to international standards. Furthermore, lead accumulated during summer seasons were very close to the maximum authorised threshold level according to the Food Act 1998 and transgressed the threshold for the WHO. In conclusion, the fish species studied can be considered safe for consumption with close monitoring required for summer catches with respect to the level of lead and chromium and further studies are required to confirm this trend.

Periodical monitoring of heavy metals in commercial fishes are needed for safety evaluations and environmental water quality should be assessed. Other similar studies have to be conducted with a greater number of fish samples to confirm the trend set in this study. The Food Act 1998 should be revised to include threshold levels for a greater number of heavy metals especially chromium since the latter exceeded international boundaries and should be compared with agencies such as the WHO and the MAFF. Sensitisation campaigns should be carried out to inform the general population about the risk of heavy metals toxicity. Gynaecologists should be encouraged to inform patients about the risk of eating certain fish (heavy metal bioaccumulators) that can affect foetal growth.

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