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Theoretical Risk Ranking of Commonly Consumed Processed Philippine Fish Species with and without Phosphorus-containing Additives

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A framework of theoretical calculations based on the review of published information was used to determine possible risks due to dietary phosphorus in identified commonly consumed Philippine fish species – including tilapia, milkfish, round scad, and yellowfin tuna. The reported individual consumption data and mean body weight of various age groups starting from preschool (6 mo – 5 y/o) to elderly (≥60 y/o) in the Philippines, the standardized maximum tolerable daily intake of phosphorus, and the phosphorus levels in EP of fish species were utilized to calculate worst-case scenario risk values. The background phosphorus levels of fish species were based on their corresponding reported natural mineral content, while total phosphorus content was calculated from the background phosphorus in addition to the allowable maximum guideline value for phosphorus additive in processed fish products. Theoretical results showed that all age groups are at low risk in the consumption of the identified fish species, with or without phosphorus-containing additives, based on the ranking. The study recommended the validation of the framework of calculation by its application to other food additives. A supplemental study for the validation of the background phosphorus levels in raw test fish species and the total phosphorus levels in processed products with the additive commercially sold in the market was also recommended.

Key words: dietary phosphorus, milkfish, risk ranking calculation, round scad, tilapia, tuna

INTRODUCTION

The scientific ranking of food hazards associated with human exposure per food type could usher the establishment of strategies from a well-defined starting point necessary for risk-based priority setting and proper allocation of resources strictly focused on the development of policies and actions for addressing them (EFSA 2012, Sumner & Ross 2002). Risk ranking has been reported to be the first determining step before a comprehensive risk-based surveillance should be done (Berg 2008, van Asselt *et al*. 2013).

Related to chemical hazards associated with food, those containing additives are more prominent to address. In the advent of food science and technology progress to meet the increasing demand for the continued supply of shelf-stable food products, more chemical additives are approved for use in processed forms of food. Unfortunately, misuse of additives in food may lead to health problems of exposed consumers either as a result of severe short-term acute exposure or long-term chronic exposures. Such is the case in the utilization of functional additives in meat and fishery products that now commonly apply phosphates, nitrites, and nitrates to enhance sensory qualities, yield, and shelf stability of processed products (Chen 2011).

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The Philippine food and beverage manufacturing industries are established important sectors of the Philippine economy (Macabasco 2011). In 2017, the subsector with the highest retail value growth of 9% is the processed seafood industry with a recorded positive performance of processed milkfish and other product options – including fish balls, squid balls, and shrimp balls in the market (Euromonitor International 2017). The forecasted retail sales value of frozen processed food in the Philippines is even expected to reach over a billion U.S. dollars by 2018 (Statista 2018). More recently, milkfish, round scad, tilapia, and tuna were reported to remain as major sources of calorie intakes in the Philippines (PSA 2017a).

It has been reported that phosphorus-containing additives in the form of food-grade phosphates have many functional uses in fishery products – including enhancement of water retention, control of lipid oxidation, protection improvement against protein denaturation during frozen storage, extension of shelf-life, and improvement of cooking yield (Anggraeni *et al*. 2017, Lampila 2013). The US Food and Drug Administration (USFDA) categorize food-grade phosphate as "Generally Recognized as Safe" (GRAS), stating that its evaluation of the additive category indicates no reasonable grounds to suspect a hazard to the US consumers in their current levels of usage or even in expected usage in the future (USFDA 2017). Canada and the European Community, however, restrict the phosphate usage to 0.5% reported as P_2O_5 (phosphorus peroxide) or 5 g/kg as a maximum level of use in the fishery products (CFIA 2016, EPC 2010). The Philippine FDA similarly controls phosphate use in fishery products following CODEX guidelines, which established the maximum use level at 2200 mg/kg as phosphorus (CAC 2017). Unlike other food additives, phosphorus is also regarded as a micronutrient; the Joint FAO/WHO Expert Committee on Food Additives (JECFA) set a maximum tolerable daily intake (MTDI) for phosphoric acid and phosphate salts at 70 mg/kg in terms of phosphorus (WHO 2018).

Human health problems resulting from excessive dietary phosphorus have been attributed to changes in the calcium metabolism contributing to bone loss plus kidney and heart problems (Trautvetter *et al*. 2015, Uribarri 2009). High phosphorus levels in the body resulting from excessive intake of food with phosphorus-containing additives are particularly lethal to patients with chronic renal failure undergoing hemodialysis, as well as to cardiovascular patients (Anggraeni *et al*. 2017, Ritz *et al*. 2012, Savica *et al*. 2016). Karalis and Murphy-Gutekunst (2006) reported that the public may be consuming more phosphorus in their diet because phosphorus-containing additives in processed products are more readily absorbed than naturally occurring phosphorus in food. The aim of this study was to present a theoretical calculation framework for worst-case scenario risk ranking of dietary phosphorus in identified commonly consumed fish species in the Philippines – including milkfish (*Chanos chanos* Forsskal), tilapia (*Tilapia mossambica*), yellowfin tuna (*Neothunus macropterus*), and round scad (*Decapterus macrosoma*) for different age groups in the Philippines.

METHODOLOGY

This study reviewed pertinent literatures on dietary phosphorus and its harmful effects upon excess intake. Likewise, it tried to synthesize data on the most commonly consumed fish species and the demographics of the general population, including the individual food consumption (IFC) of fish species in the Philippines. Literature review on worst-case scenario risk calculations were utilized to theoretically assess the worst-case scenario risk ranking of dietary phosphorus in reported commonly consumed fish species in the Philippines for different age groups in the Philippines.

The identification of the commonly consumed fish species in the Philippines included in this study were based on the following references: Food Consumption and Nutrition Report No. 2017-6 (PSA 2017b); The Consumption of Fish and Fish Products in the Asia-Pacific Region based on Household Surveys from the Food and Agriculture Organization of the United Nations (FAO) (Needham & Funge-Smith 2015); and Commodity Fact Sheets from 2013 to 2016 (PSA 2014, 2015, 2016, 2017a).

The 8th National Nutrition Survey (NNS) – Dietary Survey reported information on IFC of fish and fish products (g food/d/food group) in the Philippines by the general population based on the age groups clustered by the Department of Science and Technology – Food and Nutrition Research Institute (DOST-FNRI) (2015c). The mean body weight data for both sexes of preschool (6 mos – 5 y/o), school age (6–12 y/o), and adolescents (13–18 y/o) was extracted from the Anthropometric Survey (DOST-FNRI 2015b) and re-calculated according to the age ranges in the 8th NNS – Dietary Survey (DOST-FNRI 2015c). Meanwhile, the averages of the reported mean body weight of male and female for the adults (19–59 y/o) extracted from the 8th NNS (DOST-FNRI 2015a) and that of the elderly (≥ 60 y/o) extracted from a study of Barba and Cabrera (2008) entitled "Recommended energy and nutrient intakes for Filipinos 2002" were calculated to get the mean body weight of both sexes.

The online database of Philippine Food Composition Tables (FCT) 2018 provided the percent edible portion (EP) in raw fish of the species used in this study (DOST-FNRI 2018). Using these, the IFC of fish and fish products of each age group was computed using the following equation:

IFC of Fish and Fish Products (g EP of raw fish) = Reported IFC of Fish and Fish Products (raw as purchased, g) x (EP in Raw Fish (%) / 100) (1)

This study theoretically calculated two types of dietary exposure based on background phosphorus concentration (BPC) and total phosphorus concentration (TPC) as the summation of the BPC plus the allowed phosphorus-containing additive concentration (APAC). The levels of background phosphorus (mg P/100 g EP of food) naturally occurring in the identified species were obtained from the FCT (DOST-FNRI 2018). The CODEX STAN 192–1995 provided the maximum APAC (mg P/kg food material) incorporation as an additive to processed fish products (CAC 2017). To calculate the APAC supposedly consumed, Equation 2 was used. TPC with additive was calculated using Equation 3.

APAC (mg P/100g E.P. in raw fish) = Maximum APAC (mg P/kg EP of raw fish) / 10 (2)

TPC with Additive (mg P/100 g EP of fish) = BPC (mg P/100 g EP of raw fish) + APAC (mg P/100 g EP of raw fish) (3)

To calculate the dietary exposure of phosphorus, the equation provided by Low *et al.* (2004) for worst-case exposure was adapted and modified as follows:

Dietary Exposure (mg P) = Food Consumption (g EP of raw fish) x [Food Chemical Concentration (mg P/100 g EP of raw fish) / 100] (4)

After the calculation of dietary exposure, a worst-case scenario phosphorus risk adapted from Low *et al.* (2004) can be calculated using the following equation:

Risk = Dietary Exposure (mg P) / MTDI (mg P) (5)

Where:
MTDI (mg P) = Recommended MTDI (mg P/kg body weight) x Body Weight (kg) (6)

The recommended MTDI of phosphorus per body weight (mg P/kg body weight) was set by JECFA (WHO 2018, EFSA 2013). The MTDI of phosphorus for specific age groups in the Philippines were calculated as the product of the recommended MTDI and the computed mean body weight per age group. The risks for both with and without phosphorus-containing additive were computed. An age group was considered to be safe with the risk associated with dietary phosphorus in terms of their consumption of fish and fish products and body weight if calculated risk < 1. A risk ranking according to age groups was generated for each fish species. The age group with the highest calculated risk was ranked as 1 and the lowest was ranked 5. A scatter plot was generated to assess the overall risk of the different age groups to phosphorus in the four major Philippine fish species commonly consumed with or without the phosphorus-containing additive.

RESULTS AND DISCUSSION

Results

The reported four major fish species commonly consumed in the Philippines as of 2016 were tilapia, milkfish, round scad, and tuna (PSA 2014, 2015, 2016, 2017a, 2017b). These identified fish species were used in this study for theoretical risk ranking based on phosphorus levels. The sequence of the four major fish species commonly consumed in the Philippines based on their TPC (mg P/100g EP of raw fish), which is derived from the EP and BPC of the test species reported in the FCT (DOST-FNRI 2018), and the APAC established by CODEX STAN 192–1995 for fish, which amounts to 220 mg P/100g EP of raw fish (CAC 2017) is: yellowfin tuna (691) > round scad (432) > milkfish (414) > tilapia (404).

The theoretically calculated worst-case scenario risk ranking of phosphorus in terms of background and additive in the four major commonly consumed Philippine fish species for various age groups are shown in Tables 1 to 4. Tables 1 and 2 present the theoretically calculated risk ranking of tilapia and milkfish, which are cultured fish species. On the other hand, Tables 3 and 4 indicate the computed theoretical risk ranking of round scad and yellowfin tuna, which are fish species harvested from the marine environment.

Figure 1 presents the scatter plot of the consolidated risk ranking of commonly consumed processed Philippine fish species with and without phosphorus additive. This overall ranking was generated from the theoretical data calculated based on worst-case scenario in Tables 1 to 4 to understand which age group may be the most susceptible to risk associated with dietary phosphorus intake and which among the four major test species in this study should be prioritized in monitoring for safe intake in terms of the mean body weight and the consumption data gathered for each age group. The results of this study generated 40 data points. The point ranked as 1.00 (40/40), which in this case is school age children consuming yellowfin tuna with phosphorus-containing additive, has the highest risk value and therefore the most susceptible. The lowest point 0.025 (1/40), adolescents consuming unprocessed tilapia, has the lowest risk value and considered the least susceptible.

Table 1. Risk ranking of phosphorus in tilapia for different age groups in the Philippines.

	A	B	C	D	E	F	G	H1	H2	I	J1	J2	K
				= B(C/100)	= (E*/100)	= (F*/1000)	= E+F	= D(E)	= D(G)	= MTDI* x A	=H1/I	=H2/I	
Age Group	**Mean Body Weight** *(kg)*	**IFC of Fish and Fish Products** *(raw as purchased, g)*	**EP in Raw Tilapia** (%)	**IFC of Fish and Fish Products** *(g EP of raw tilapia)*	**BPC**	**APAC**	**TPC with Additive**	**Exposure** (without additive)	**Exposure** (with additive)	**MTDI**	**Risk** (without additive)	**Risk** (with additive)	**Rank**
					(mg P/g edible portion of raw tilapia)			*(mg P)*		*(mg P)*			
Preschool[1] (6 mo – 5 y/o)	12.43	30.00		13.80				25.39	55.75	870.33	0.029	0.064	2
School age[1] (6–12 y/o)	25.86	65.00		29.90				55.02	120.80	1,810.00	0.030	0.067	1
Adolescents[1] (13–18 y/o)	46.27	81.00	46.00	37.26	1.84	2.20	4.04	68.56	150.53	3,238.67	0.021	0.046	5
Adults[2] (19–59 y/o)	57.80	106.00		48.76				89.72	196.99	4,046.00	0.022	0.049	4
Elderly[3] (≥60 y/o)	55.00	108.00		49.68				91.41	200.71	3,850.00	0.024	0.052	3

A – calculated from data reported by DOST-FNRI (2015c[1], 2015a[2]) and Barba and Cabrera (2008)[3]
B – average daily consumption; reported in 8th National Nutrition Survey – Dietary Survey (DOST-FNRI 2015c)
C – reported in the FCT (DOST-FNRI 2018)
E – E* = reported as mg P/100g edible portion of raw fish; reported in the FCT (DOST-FNRI 2018)
F – *F* = 2200 mg/kg food material*; established by CODEX STAN 192–1995 (CAC 2017)
I – *MTDI* = 70mg/kg body weight*; reported by JECFA (WHO 2018)

Table 2. Risk ranking of phosphorus in milkfish for different age groups in the Philippines.

	A	B	C	D	E	F	G	H1	H2	I	J1	J2	K
				= B(C/100)	= (E*/100)	= (F*/1000)	= E+F	= D(E)	= D(G)	= MTDI*xA	=H1/I	=H2/I	
Age Group	**Mean Body Weight** *(kg)*	**IFC of Fish and Fish Products** *(raw as purchased, g)*	**EP in Raw Tilapia** (%)	**IFC of Fish and Fish Products** *(g EP of raw tilapia)*	**BPC**	**APAC**	**TPC with Additive**	**Exposure** (without additive)	**Exposure** (with additive)	**MTDI**	**Risk** (without additive)	**Risk** (with additive)	**Rank**
					(mg P/g edible portion of raw tilapia)			*(mg P)*		*(mg P)*			

Table 2 continuation

Preschool[1] (6 mo – 5 y/o)	12.43	30.00		19.50				37.83	80.73	870.33	0.043	0.093	2
School age[1] (6–12 y/o)	25.86	65.00		42.25				81.97	174.92	1810.00	0.045	0.097	1
Adolescents[1] (13–18 y/o)	46.27	81.00	65.00	52.65	1.94	2.20	4.14	102.14	217.97	3238.67	0.032	0.067	5
Adults[2] (19–59 y/o)	57.80	106.00		68.90				133.67	285.25	4046.00	0.033	0.071	4
Elderly[3] (≥60 y/o)	55.00	108.00		70.20				136.19	290.63	3850.00	0.035	0.075	3

A – calculated from data reported by DOST–FNRI (2015c[1], 2015a[2]) and Barba and Cabrera (2008)[3]
B – average daily consumption; reported in 8th National Nutrition Survey – Dietary Survey (DOST-FNRI 2015c)
C – reported in the FCT (DOST-FNRI 2018)
E – E* = reported as mg P/100g edible portion of raw fish; reported in the FCT (DOST-FNRI 2018)
F – *F* = 2200 mg/kg food material*; established by CODEX STAN 192–1995 (CAC 2017)
I – *MTDI* = 70mg/kg body weight*; reported by JECFA (WHO 2018)

Table 3. Risk ranking of phosphorus in round scad for different age groups in the Philippines.

	A	B	C	D	E	F	G	H1	H2	I	J1	J2	K
				= B(C/100)	= (E*/100)	= (F*/1000)	= E+F	= D(E)	= D(G)	= MTDI* x A	=H1/I	=H2/I	
								Exposure			Risk		
Age Group	**Mean Body Weight** *(kg)*	**IFC of Fish and Fish Products** *(raw as purchased, g)*	**EP in Raw Tilapia** (%)	**IFC of Fish and Fish Products** *(g EP of raw tilapia)*	**BPC**	**APAC**	**TPC with Additive**	(without additive)	(with additive)	**MTDI**	**Maximum Tolerable Daily Intake**	(without additive)	(with additive)	**Rank**
					(mg P/g edible portion of raw tilapia)			*(mg P)*		*(mg P)*	*(mg P)*			
Preschool[1] (6 mo – 5 y/o)	12.43	30.00		14.70				31.16	63.50	870.33	0.036	0.073	2
School age[1] (6–12 y/o)	25.86	65.00		31.85				67.52	137.59	1810.00	0.037	0.076	1
Adolescents[1] (13–18 y/o)	46.27	81.00	49.00	39.69	2.12	2.20	4.32	84.14	171.46	3238.67	0.026	0.053	5
Adults[2] (19–59 y/o)	57.80	106.00		51.94				110.11	224.38	4046.00	0.027	0.055	4
Elderly[3] (≥60 y/o)	55.00	108.00		52.92				112.19	228.61	3850.00	0.029	0.059	3

A – calculated from data reported by DOST-FNRI (2015c[1], 2015a[2]) and Barba and Cabrera (2008)[3]
B – average daily consumption; reported in 8th National Nutrition Survey – Dietary Survey (DOST-FNRI 2015c)
C – reported in the FCT (DOST-FNRI 2018)
E – E* = reported as mg P/100g edible portion of raw fish; reported in the FCT (DOST-FNRI 2018)
F – *F* = 2200 mg/kg food material*; established by CODEX STAN 192–1995 (CAC 2017)
I – *MTDI* = 70mg/kg body weight*; reported by JECFA (WHO 2018)

Table 4. Risk ranking of phosphorus in yellowfin tuna for different age groups in the Philippines.

	A	B	C	D	E	F	G	H1	H2	I	J1	J2	K
				= B(C/100)	= (E*/100)	= (F*/1000)	= E+F	= D(E)	= D(G)	= MTDI* x A	=H1/I	=H2/I	
								Exposure			**Risk**		
Age Group	**Mean Body Weight** *(kg)*	**IFC of Fish and Fish Products** *(raw as purchased, g)*	**EP in Raw Tilapia** (%)	**IFC of Fish and Fish Products** *(g EP of raw tilapia)*	**BPC**	**APAC**	**TPC with Additive**	(without additive)	(with additive)	**MTDI**	(without additive)	(with additive)	**Rank**
					(mg P/g edible portion of raw tilapia)			*(mg P)*		*(mg P)*			
Preschool[1] (6 mo – 5 y/o)	12.43	30.00		20.10				94.67	138.89	870.33	0.109	0.160	5
School age[1] (6–12 y/o)	25.86	65.00		43.55				205.12	300.93	1810.00	0.113	0.166	3
Adolescents[1] (13–18 y/o)	46.27	81.00	67.00	54.27	4.71	2.20	6.91	255.61	375.01	3238.67	0.079	0.116	4
Adults[2] (19–59 y/o)	57.80	106.00		71.02				334.50	490.75	4046.00	0.083	0.121	2
Elderly[3] (≥60 y/o)	55.00	108.00		72.36				340.82	500.01	3850.00	0.089	0.130	1

A – calculated from data reported by DOST–FNRI (2015c[1], 2015a[2]) and Barba and Cabrera (2008)[3]
B – average daily consumption; reported in 8^{th} National Nutrition Survey – Dietary Survey (DOST-FNRI 2015c)
C – reported in the FCT (DOST-FNRI 2018)
E – E* = reported as mg P/100g edible portion of raw fish; reported in the FCT (DOST-FNRI 2018)
F – *F* = 2200 mg/kg food material*; established by CODEX STAN 192–1995 (CAC 2017)
I – *MTDI* = 70mg/kg body weight*; reported by JECFA (WHO 2018)

DISCUSSION

The four fish species used in this study were identified to be the major sources of calories in terms of fishery products in the Philippines (PSA 2017b). The historical average of production in terms of value in million pesos (Php) from 2013 to 2016 (PSA 2014, 2015, 2016, 2017a) of each species resulted in the following order: tuna (41,677.50) > milkfish (35,760.47) > tilapia (21,912.57) > round scad (13,992.72); with tuna statistics inclusive of the following species: big-eyed, skipjack, yellowfin, eastern little, and frigate.

For the purpose of this study, the basis of calculation for phosphorus risk in a food product included both the naturally occurring phosphorus as background phosphorus in the unprocessed food material and the phosphate additive incorporated during processing as similarly reported by Anggraeni *et al*. (2017). Among the varieties of tuna available in the Philippines, the only varieties that have reported background phosphorus levels from DOST-FNRI (2018) are yellowfin tuna and frigate tuna, with yellowfin having higher background phosphorus levels than the latter. Yellowfin tuna was found to have higher background phosphorus than frigate tuna, perhaps because of its reported diet consisting of larger marine preys compared to that of the smaller frigate tuna (FAO 2000). Other commercially available tuna varieties include big-eyed tuna, skipjack tuna, and eastern little tuna. The FCT reported values of phosphorus concentration per 100 g EP of foods (DOST-FNRI 2018). These were considered as the background concentrations of phosphorus in the fish species being evaluated in this study. On the other hand, the maximum APAC based on CODEX STAN 192–1995 is 2200 mg P per kg or 220 mg P/100 g food material for all frozen fish and fish products (CAC 2017).

The calculated total phosphorus concentrations of the test fish species showed that marine fishes such as round scad (FAO 2008) and tuna (Goujon & Majkowski 2000) have higher background phosphorus compared to the fish species commonly cultured in brackish water such

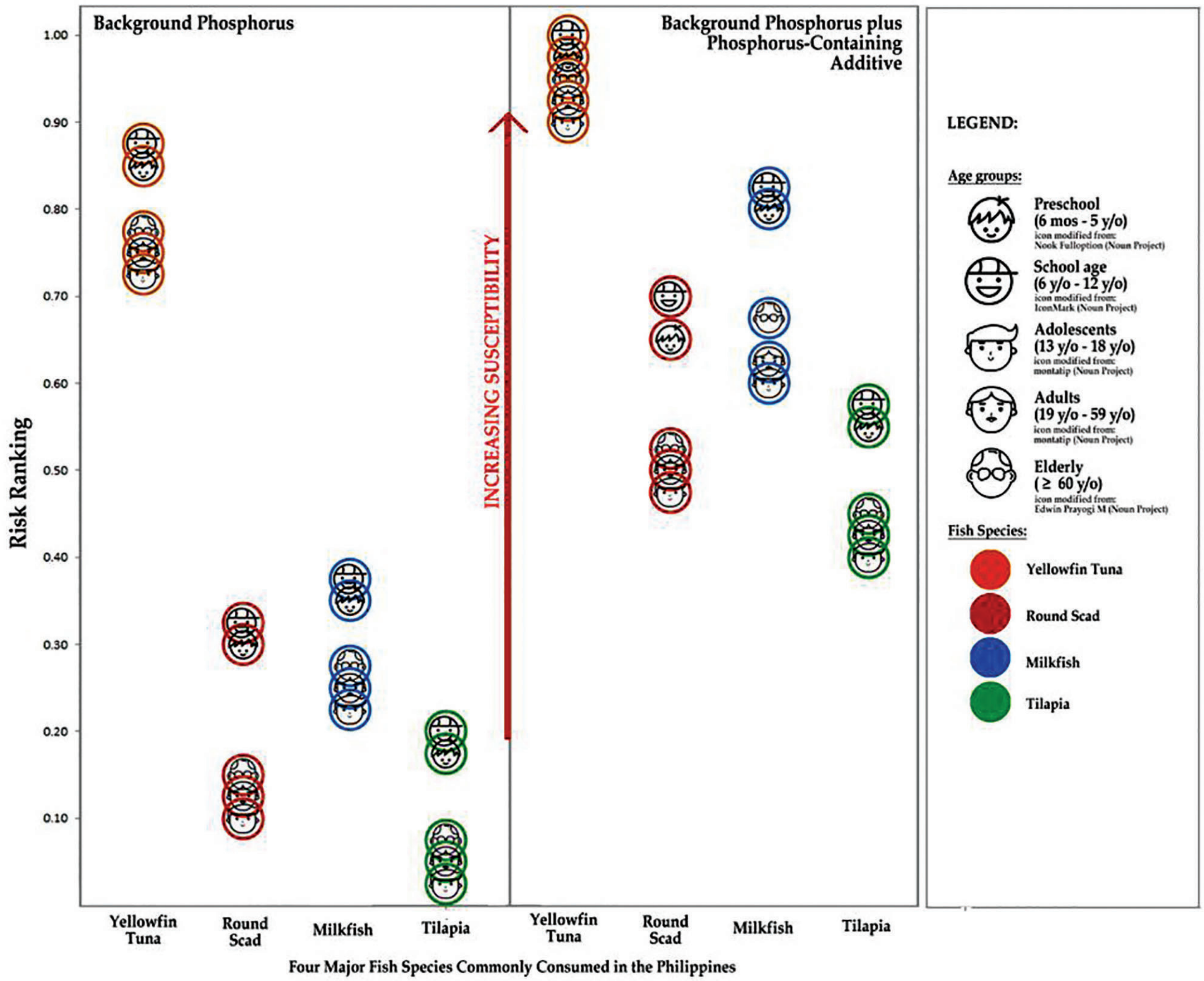

Figure 1. Scatter plot of consolidated risk ranking of commonly consumed processed Philippine fish species with and without phosphorus additive (icons modified from The Noun Project: thenounproject.com).

as milkfish (FAO 2016) and tilapia (Boyd 2004). The nutritional composition of fishes in general, whether farmed or harvested from the wild, is highly dependent on the amount and quality of its food intake, the fishing grounds, and the season of harvest (Murray & Burt 2001).

Fish nutrients from food are used either in metabolic processes, in the formation of new body tissues for growth and energy gain, or are excreted as waste in feces (Mourente & Tocher 2009). Phosphorus – also a macro-mineral component in fishes – is usually bound *in vivo* to proteins, lipids, and other intracellular organic molecules, which makes it readily available in the fish flesh or muscle (Noori *et al*. 2010). This mineral is important in the fish diet as it is an essential nutrient in the human diet (Anggraeni *et al*. 2017, Uribarri & Calvo 2003). It is not only important in growth and bone mineralization but also in energy reactions, homeostasis, metabolism, and structure (Borlongan & Satoh 2001, Roy *et al*. 2002).

Farmed fishes such as milkfish and tilapia are given flour and feeds enriched with bioavailable phosphorus for rapid growth. This method of fish cultivation drastically increases the phosphorus content in the edible parts of the fishes (D'Alessandro *et al*.2015). Meanwhile, round scad and tuna are meso-carnivorous or predatory as they feed on various species from zooplanktons to crustaceans, cephalopods, and other fish species where they get can their macronutrients, including phosphorus (Dalzell 1993, Mourente & Tocher 2009).

Aside from naturally occurring phosphorus in raw materials, food products are incorporated with phosphorus-containing additives to enhance processed product quality and shelf-life (Carrigan *et al*. 2014). However, excess in dietary phosphorus is detrimental to human health. Hyperphosphatemia, the condition of having abnormally elevated phosphorus levels in the body, interferes calcium metabolism and affects aging and cell growth; it leads to renal, bone, cardiovascular diseases, and in worst case scenarios – death (Anggraeni *et al*. 2017, Ritz *et al*. 2012).

Fortunately, the theoretical framework of calculation based on worst-case scenario shown in Tables 1 to 4 of this study indicated that the risk factors are all <1. A risk value of <1 is considered as "low risk" in relation to the ratio of exposure (to phosphorus) and MTDI (of phosphorus) as calculated. The risk value of <1 signifies that the age group consumes the particular food commodity with a certain level of phosphorus content within tolerable daily intake. This also confirms the veracity of the maximum limit of use set by CODEX for phosphorus-containing additives to 2200 mg/kg. To assess the validity of the theoretical framework of calculation presented it this study, it was also used to calculate for the risk associated with dietary phosphorus in other commonly consumed commodities such as pork, beef, and chicken. The results showed that the risk values were all <1 on all tested commodities for all age groups. The framework may further be validated using other food additives such as nitrite and nitrate, which equally pose severe risks to consumers if used in excess.

In terms of calculated susceptibility to risk due to dietary phosphorus, the theoretical risk ranking in terms of the age groups was shown to be influenced by the ratio of reported food consumption to the reported body weight (g EP of raw fish / kg body weight) and established the following pattern within each species: school age (2.51) > preschool (2.41) > elderly (1.96) > adults (1.83) > adolescents (1.75). Overall, it was observed that the reported individual daily consumption of fish products increase with mean body weight and age, except for the elderly (Barba & Cabrera 2008; DOST-FNRI 2015a, 2015c). School age and preschool age groups have relatively higher consumption with respect to their body weight, which made them the most susceptible based on the theoretical worst-case risk calculation. Similarly, the elderly became more susceptible compared with adults and adolescents because of higher reported consumption of fish and fish product despite the decline in weight of the age group.

Between fish species and processing state involving use of additive, the general risk rank order was: yellowfin tuna with additive > yellowfin tuna without additive > milkfish with additive > round scad with additive > tilapia with additive > milkfish without additive > round scad without additive > tilapia without the additive. This pattern may be attributed to the reported BPC and EP, which could be traced back to the variation in fish diet and fish-capture environment. Yellowfin tuna has the highest recorded background phosphorus and EP among the four species. Although the reported background phosphorus level of round scad is higher than milkfish, the calculated risk is lower for all age groups because its reported EP is lower than that of the latter, thereby decreasing the amount of phosphorus in the food available for consumption. The findings of this study need validation of BPC of the fish species, as well as the residual phosphorus content upon the addition of the additive. Actual analyses to validate these theoretical results are highly recommended.

CONCLUSION

The present study generated a theoretical framework of calculations for the assessment of the susceptibility of different Philippine age groups to worst-case risk due to dietary phosphorus in identified commonly consumed Philippine fish species – including tilapia, milkfish, round scad, and yellowfin tuna whether in the form of background phosphorus or with phosphorus-containing additives as in processed fish products through risk ranking. The theoretical results based on worst-case risk calculation showed low risk to dietary phosphorus in all test species for all age groups.

In terms of susceptibility, the risk ranking showed the following pattern for the age groups: school age > preschool > elderly > adults > adolescents. Correspondingly, the following general order of risk of the fish species was theoretically established: yellowfin tuna > milkfish > round scad > tilapia and; the presence of additive > without additive. The results showed that the consumption of fish and fish products by the different age groups are within the limits set by the MTDI for the mineral. The risk ranking only showed which fish species and age groups should be prioritized when it comes to risk assessment. The results also positively support the safety of the maximum guideline value set by CODEX for phosphorus-containing additives use in fishery products.

The theoretical framework of calculations conceptualized from this study can be utilized to help establish risk ranking of other food matrices with other chemical hazards in the future. However, the validity of the theoretical calculation must still be subjected to further studies to validate phosphorus levels in fresh and processed food products of concern. Hopefully, data from this study can be initially utilized by local health stake players to monitor and control health impact of dietary phosphorus from commonly consumed fish products while awaiting validation results of recommended further studies.

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