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Risk-benefit of consuming Lake Erie fish

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ABSTRACT

Background: Consumption of fish is promoted as a healthy way to obtain essential fatty acids (EFA) in the diet, yet the risk of ingesting harmful contaminants remains a concern. A recent study concluded that the risk-benefit of consuming fish from the North American Laurentian Great Lakes, which sustain important commercial and recreational fisheries, is currently unclear. We report the fatty acid (FA) content in skin-off fillets of fifteen fish species from Lake Erie and assess whether recommended dietary requirements for two EFA (EPA and DHA) can be met by safely consuming Lake Erie fishes, as an example of a risk-benefit analysis.
Methods: A total of 146 samples were analyzed for FA and contaminant content. A simulated fish consumption advisory (maximum recommended number of meals per month, up to 32) was calculated for each sample, and used to calculate the maximum amount of EPA+DHA that would be consumed if the consumption advisory was followed.
Results: All fifteen species had nutritionally desirable PUFA:SAFA (>0.4) and n−3:n−6 (>1). Large, fatty species had the highest EPA+DHA content, but had the most restrictive consumption advisories due to high PCB concentrations. To minimize contaminant exposure while maximizing EPA+DHA intake, consumers should consider small lake whitefish and lake trout, small panfish species, and/or walleye. However, very few species had an EPA+DHA content sufficient to safely meet the highest dietary guidelines while following advisories.
Conclusions: Consumption of certain Lake Erie fish, an important recreational and commercial fishery, within the limits of our simulated fish consumption advisories, can be a good supplemental source of beneficial n-3 long chain PUFA.

1. Introduction

The North American Laurentian Great Lakes have been affected over the past several decades by numerous stressors, including but not limited to, toxic substances such as polychlorinated biphenyls (PCBs), dioxins, mercury and pesticides (Bhavsar et al., 2010, 2008, 2007). These stressors have directly and indirectly impacted biota of the Great Lakes and have had negative implications for important commercial and recreational fisheries valued at a total of >$4 billion annually (Great Lakes Information Network, 2012). In particular, the accumulation of contaminants in fish has resulted in the issuance of restrictive fish consumption advisories (Illinois Department of Natural Resources, 2013; Ohio Environmental Protection Agency, 2012; Ontario Ministry of the Environment, 2013).

Abbreviations: ALA, α-linolenic acid (18:3n−3); DHA, docosahexaenoic acid (22:6n−3); EFA, essential fatty acid(s); EPA, eicosapentaenoic acid (20:5n−3); FA, fatty acid(s); FAME, fatty acid methyl ester(s); FAO, Food and Agricultural Organization; LC-PUFA, long chain (i.e., ≥20 carbons) polyunsaturated fatty acid(s); LIN, linoleic acid (18:2n−6); MUFA, monounsaturated fatty acid(s); OMOE, Ontario Ministry of the Environment; OMNR, Ontario Ministry of Natural Resources; PCBs, polychlorinated biphenyls; PUFA, polyunsaturated fatty acid(s); SAFA, saturated fatty acid(s); WHO, World Health Organization

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While contaminant concentrations in Great Lake fishes pose a potential health risk to those who consume them (Ontario Ministry of the Environment, 2013), fish in general is promoted by nutrition and health experts as a healthy part of the human diet (Bourre and Paquotte, 2008; Health Canada, 2011). Fish and other seafood products are known to contain high quality proteins, essential nutrients such as vitamins D and B12, as well as iodine and selenium (Larsen et al., 2011). In addition, fish contain high levels of "essential" n-3 and n-6 long chain polyunsaturated fatty acids (LC-PUFA) which cannot be synthesized by the human body in amounts adequate for optimal health (Arts et al., 2001; Gerster, 1998). Essential fatty acids (EFA) have important roles in the healthy functioning of the human body and have been shown to have beneficial effects in relation to cardiovascular disease, diabetes, inflammatory diseases, and neurological health (Lands, 2009; Yashodhara et al., 2009). Consequently, nutritional guidelines in many countries stress the importance of including fish in the diet as a source of EFA (Kris-Etherton et al., 2009).

Thus, advice concerning the consumption of fish can be contradictory, depending on whether consumption advice is generated by contaminant levels (e.g., health risks) or nutrients such as EFA (e.g., health benefits). Ideally, both the risks and benefits of consuming fish should be considered and balanced, such that consumers achieve maximum EFA intake with minimal intake of potentially harmful contaminants. Several studies have addressed this by providing dietary advice after considering the nutritional benefits against the possible risks of fish consumption (Levenson and Axelrad, 2006; Mozaffarian and Rimm, 2006; Mozaffarian, 2009) while other studies have taken more quantitative approaches (Dewailly et al., 2007; Domingo et al., 2007; Ginsberg and Toal, 2009; Smith and Sahyoun, 2005; Stern and Korn, 2011).

Fatty acid research on Great Lakes sport fishes (i.e., species that are regularly caught and consumed by anglers) in relation to human dietary requirements has thus far been relatively scarce. While earlier studies reported FA content for selected species and locations in the Great Lakes (Chan et al., 1999; Wang et al., 1990), Turyk et al. (2012) recently concluded that the lack of data concerning $n-3$ EFA in Great Lakes sport fish populations is a hindrance to risk-benefit analyses. More recent studies have presented additional FA content for lake trout and/or lake whitefish in the Great Lakes (Moths et al., 2013; Pantazopoulos et al., 2013); however, a comprehensive view of FA content for a variety of other fish species present in the Great Lakes is still lacking. Further, although the risks of consuming Great Lakes sport fish are well-documented (Illinois Department of Natural Resources, 2013; Michigan Department of Community Health, 2013a; Ontario Ministry of the Environment, 2013), to our knowledge there have been no quantitative risk-benefit analyses on consumption of Great Lakes fishes in the published literature. As ~4.2 million adults in the U.S. Great Lakes region consumed at least one Great Lakes fish meal over the course of a year, and consumption of sport fish by children is related to that of their parents (Imm et al., 2007, 2005), FA data are needed to provide consumption advice that not only considers the potential risks of consuming Great Lakes fishes, but also the benefits.

In this study, we report the FA content and composition of 15 fish species from Lake Erie, with particular focus on EPA and DHA (n-3 LC-PUFA). We then assess the relative benefits of consuming Lake Erie fishes in terms of EPA+DHA intake, with the relative risk due to environmental contaminants. This is assessed by determining whether EPA+DHA dietary guidelines can be met by consuming Lake Erie fish, while adhering to consumption advisories due to contaminants. This analysis is particularly relevant given the importance of Lake Erie to commercial, recreational and possibly subsistence fishing interests in the U.S. and Canada. For example, the freshwater commercial fishery in Lake Erie is the largest in the Great Lakes and Canada (valued at $194 million in 2011; (Ontario Ministry of the Environment, 2012)), and is the most popular Great Lake amongst U.S. anglers for recreational fishing (U.S. Fish & Wildlife Service 2011).

2. Materials & methods

2.1. Sample collection and laboratory analysis

The Sport Fish Contaminant Monitoring Program of the Ontario Ministry of the Environment (OMOE) has analyzed skinless, boneless fish muscle tissue from over 2000 locations within Ontario for a suite of contaminants since the 1970s. To conduct a risk-benefit analysis of fish consumption, 146 samples of 15 fish species from Lake Erie were selected from the Program's tissue bank for additional fatty acid analysis. In order to capture spatial, seasonal and gender variability, samples of both male and female fish were selected, having been collected between April and October (i.e., the most popular period for fishing) of 2010, from one or more regions within Lake Erie, including the western basin (LE1), central basin (LE2), Rondeau Bay (LE2a), Long Point Bay (LE3), and the eastern basin (LE4) (Table S1).

All samples were analyzed for FA content, as well as contaminants of concern in the Great Lakes, including mercury, total PCBs, mirex, photomirex, toxaphene, and total chlordane. Within the Canadian waters of Lake Erie, fish consumption restrictions are due to elevated levels of PCBs and/or mercury (Bhavsar et al., 2011; Ontario Ministry of the Environment, 2013). New York, Ohio, Pennsylvania and Michigan state agencies have also issued restrictive fish consumption advisories for the American waters of Lake Erie due to elevated levels of PCBs (State of the Great Lakes, 2009). In this analysis, concentrations of mirex, photomirex, toxaphene and total chlordane for all fish samples were too low to result in consumption advisories, and were thus not considered further. For black crappie, bluegill and pumpkinseed, the 2010 samples used for FA analysis had only been tested for mercury concentrations, as this is generally the most restrictive contaminant for these species in Lake Erie (OMOE unpublished data). However, to confirm that mercury was the consumption-limiting contaminant for these species, PCB concentrations in samples collected from the same location within Lake Erie in 2009 were examined (OMOE unpublished data). In all cases, PCB concentrations were too low to generate consumption advisories more restrictive than the restrictions due to mercury concentration, and so the 2009 samples were not included in the analysis.

After collection, fish were measured for total length and weight, sexed, and then filleted (skin removed) and stored at -20 °C until chemical analysis at the OMOE laboratory in Toronto, ON, and FA analysis at the Environment Canada laboratory in Burlington, ON. Samples were analyzed for contaminants using accredited OMOE methods (Gewurtz et al., 2011; Ontario Ministry of the Environment, 2007, 2006)). Methodology for FA extraction is described in full in the Supplementary material.

2.2. Fatty acid profiles and risk-benefit calculation

Four individual FA out of the 47 that were identified in the laboratory analysis are highlighted due to their nutritional importance: linoleic acid (LIN, 18:2$n-6$), α-linolenic acid (ALA, 18:3$n-3$), eicosapentaenoic acid (EPA, 20:5$n-3$) and docosahexaenoic acid (DHA, 22:6$n-3$). Summary measures of quantified FA were calculated including; n-3, $n-6$, total monounsaturated FA (MUFA), total saturated FA (SAFA) and total polyunsaturated FA (PUFA). FA content was examined as wet weight (ww; mg/100 g), dry weight (dw; mg/100 g), proportion of total quantified FA (%)