Journal of Food Composition and Analysis 24 (2011) 1168–1173

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Report

Challenges in estimating omega-3 fatty acid content of seafood from US nutrient databases: A salmon case study☆

Kristina Harris, Jennifer Fleming, Penny Kris-Etherton *

Department of Nutritional Sciences, College of Health and Human Development, The Pennsylvania State University, University Park, PA 16802, USA

ARTICLE INFO

Article history:
Received 19 October 2010
Received in revised form 9 March 2011
Accepted 15 March 2011
Available online 27 April 2011

Keywords:
Nutrient database
Fish
Salmon
Omega-3 fatty acids
EPA
DHA
Variability
Cardiovascular disease
Food composition

ABSTRACT

A major source of long-chain omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), is fatty fish, i.e. salmon. Compelling evidence shows fish intake decreases the risk of cardiovascular disease (CVD). The American Heart Association recommends the public eat 2 servings (3.5 oz each) of fish (preferably fatty) per week to increase EPA + DHA intake and lower CVD risk. The 2010 Dietary Guidelines for Americans recommends 8 oz of a variety of seafood per week providing an average daily consumption of 250 mg EPA + DHA. "Fish-first" recommendations rely on accurate nutrient databases to estimate the amount of EPA + DHA in fish. Wild salmon vary in total fat and EPA + DHA content depending on location, season, water temperature, age, sex, and diet. The environment of farmed salmon is controlled, but the EPA + DHA content of the feed varies. US researchers primarily rely on the USDA Nutrient Database for food composition information, while consumers likely use commercial websites; however, websites often cite USDA values making the accuracy of the database paramount. Accounting for the inherent EPA + DHA variability in wild salmon and regulating the nutrient content of feed for farmed salmon can provide more stable estimates of EPA + DHA in fish, thereby improving the accuracy of nutrient databases.

1. Introduction

High blood levels of long-chain omega-3 fatty acids (n-3 FAs), eicosapentaenoic acid (EPA, 20:5) and docosahexaenoic acid (DHA, 22:6), decrease risk of cardiovascular disease (CVD) events (Harris et al., 2008b). Intake of fatty, cold-water fish such as salmon, mackerel, and sardines, or fish oil capsules are the most effective methods of increasing EPA + DHA blood levels, as the conversion of shorter chain n-3 FA, i.e. α-linolenic acid, to EPA + DHA is minimal in humans. Intervention studies using fish oil capsules in secondary prevention settings have proven that EPA + DHA decrease risk of CVD mortality by as much as 41% (Marchioli et al., 2002; Yokoyama et al., 2007). Similarly, a meta-analysis by He et al. demonstrated that every 20-g/day increase of fish intake resulted in a 7% reduction in CVD risk in a primary prevention setting (He et al., 2004). Finally, increased erythrocyte membrane levels of EPA + DHA as a percentage of total membrane fatty acids, termed the omega-3 index, are related to a decrease in sudden cardiac death risk; thus, the omega-3 index has been introduced as a novel risk factor for CVD events (Harris, 2008). Therefore, with the purpose of decreasing CVD burden in the general US population, public health organizations recommend increasing oily fish or seafood consumption to increase population EPA + DHA blood levels, which represents a "food first" approach (Kris-Etherton et al., 2002; United States Department of Agriculture and U.S. Department of Health and Human Services, 2011).

Recommendations to increase EPA + DHA intake from foods rely on databases to provide an accurate nutrient profile of fish and seafood. Determining the amount of EPA + DHA per serving of fish provides the foundation for recommending specific amounts and types of fish to eat. Indeed, the American Heart Association (AHA) recommends at least two, 3.5 oz (preferably fatty) fish meals a week (Kris-Etherton et al., 2002), whereas 2010 Dietary Guidelines from the United States Department of Agriculture (USDA) recommends "...8 oz per week of a variety of seafood, which provide an average consumption of 250 mg/day of EPA + DHA..." (United States Department of Agriculture and U.S. Department of Health and Human Services, 2011). The former would provide an estimated 0.5 g/day (Harris et al., 2008a) and the latter, 0.25 g/day of EPA + DHA. Although the 2010 Dietary Guidelines does not specify a frequency of fish intake but rather an absolute amount, it is assumed that the 8 oz of seafood is consumed in 2, 4-oz servings in order to compare to the AHA recommendations. The discrepancy between estimated amount of EPA + DHA provided by two "fatty fish" servings versus two "seafood" servings reflects inherent

☆ This paper was an oral presentation at the 34th National Nutrient Databank Conference, Grand Forks, North Dakota (USA), July 12–14, 2010.

* Corresponding author at: 110 Chandlee Laboratory, The Pennsylvania State University, University Park, PA 16802, USA. Tel.: +1 814 863 2929; fax: +1 814 863 6103.
E-mail address: pmk3@psu.edu (P. Kris-Etherton).

0889-1575/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.jfca.2011.03.019

differences in the EPA + DHA content of fatty fish versus all seafood. Consumer education about fish and accurate food labeling is essential for EPA + DHA levels to be realized via fish intake.

The purpose of this paper is to discuss the issues that both consumers and researchers encounter in acquiring accurate values for EPA + DHA content of fish (due to multiple potential sources of information, i.e. databases, websites, literature), and the challenges for nutrient databases to capture intra-species variability of EPA + DHA due to catch conditions and feed in a single fish species. The nutrient profile of salmon will be used to illustrate these considerations.

2. Determination of EPA + DHA content in salmon in the USDA Nutrient Database

Nutrient composition of foods from the USDA Nutrient Database (Standard Reference 23) is the result of careful, standardized analysis of a sample of commonly eaten fish in the US. The USDA's National Food and Nutrient Analysis Program focuses on expanding and improving the nutrient database by establishing protocols for choosing which foods to sample, which nutrients to assess, how to prepare the samples prior to analysis, which labs to use for chemical analysis, and how to check the quality of previously analyzed data (Haytowitz et al., 2008). The majority of the nutrient profiles for fish in SR 23 (the current version of USDA nutrient database) are from scientific literature and government reports compiled in 1987; however, a new analysis of 21 species of fish and shellfish has been included. Of the newly analyzed fish, wild sockeye and pink salmon were sampled from 12 randomly selected supermarkets across the US in February 2007 and March 2008, respectively (Exler et al., 2009). Fresh samples were sent on dry ice to the Food Analysis Laboratory Control Center at Virginia Polytechnic Institute and State University for processing prior to analysis, as part of the quality control method. The edible portions of the fish were homogenized with liquid nitrogen, packaged into jars under nitrogen and stored at −65 °C in preparation for analysis at a contracted lab. Fatty acid composition was measured using gas chromatography of fatty acid methyl esters with flame ionization detection, as described in AOAC method 996.06 (Association of Analytical Communities, 2002).

The EPA + DHA values in SR 23 for wild sockeye salmon and pink salmon (fresh, cooked) were 53 and 36% lower, respectively, than those from SR 22 (Fig. 1). Sockeye salmon had lower total, mono- and polyunsaturated fat content, which helps explain the 53% lower EPA + DHA values. Pink salmon, on the other hand, had

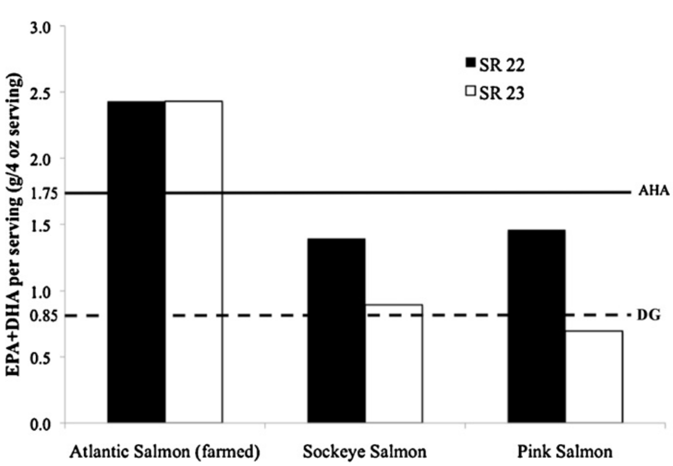

Fig. 1. Comparison of EPA + DHA values of salmon re-analyzed between USDA Nutrient Database Standard Reference 22 and 23. Amount of EPA + DHA per 4 oz serving needed to meet AHA (solid line) or Dietary Guidelines (DG) recommendation (dashed line) in 2 servings per week.

Table 1
Estimated amount of EPA + DHA required per serving of fish to achieve recommendations.

Organization	Fish intake recommendation	Estimated EPA + DHA intake (g/day)	Grams of EPA + DHA needed per serving (3.5–4 oz)
American Heart Association	Eat at least 2 servings of *fish* (*preferably fatty*) per week	0.50	1.75
Dietary Guidelines for Americans 2010	Eat 8 oz *seafood* per week	0.25	0.875

higher total and monounsaturated fat content and lower polyunsaturated fat and EPA + DHA content (nutrient composition for Atlantic salmon is identical in SR 22 and 23, indicating that only the sockeye and pink samples had updated values). The sampling dates, February and March, could have affected the total fat content, thus resulting in a reduced EPA + DHA value, as seen in sockeye salmon (see Section 4). The reasons for the higher fat content but "less favorable" fatty acid composition in pink salmon are unknown. Regardless of the possible reasons for the differences in EPA + DHA, the natural variation in fat content is a factor that should be considered when estimating or reporting EPA + DHA content of salmon. A more representative estimate of the fat composition of salmon could be achieved by sampling commercially available salmon from grocery stores over 12 months, sampling fresh caught salmon during different growth phases, at different locations and times of the year, and including the average range of EPA + DHA levels on the packaging of fresh, canned and frozen fish.

If only sockeye and/or pink salmon were used to meet the recommended intakes of EPA + DHA, neither would provide the amount recommended by the AHA for primary prevention of CVD in 2 servings (∼1.75 g EPA + DHA/serving; Table 1). Sockeye salmon would, however, provide the USDA recommended intake for overall good health (∼0.875 g EPA + DHA/serving, Table 1), based on SR 22 and 23 values. Since salmon often is considered the best source of EPA + DHA in the US diet, it is troublesome that two servings (3.5 and 4 oz) per week of salmon cannot achieve EPA + DHA recommendations. Updated analyses on other commonly eaten sources of EPA + DHA, such as farmed Atlantic salmon, are needed.

3. Comparison of EPA + DHA content of Atlantic salmon from multiple sources

Information about EPA + DHA content of fish can be found on labels, company websites, and in nutrient databases. Consumers typically use labels or websites, whereas US researchers use nutrient databases and scientific publications. The (in)consistency of the EPA + DHA content of Atlantic salmon from these four sources is presented in Tables 2 and 3 and discussed below.

3.1. Research

US researchers primarily utilize the USDA Nutrient Database as a source of nutrient composition of foods (Haytowitz et al., 2008); however, Table 2 includes other common sources for nutrient information that are available to researchers. Nutrient Data System for Research (NDSR) and Food Processor are specific programs used for analyzing 24-h recalls, dietary records and menus, and they often use information from the USDA database; however, it is possible to use nutrient data from other sources with these programs. NUTTAB is the Australian and New Zealand nutrient database (Food Standard Australia New and Zealand, 2006). Bowes