UMT PRESS

Planetary Sustainability
Journal Homepage: https://planetsust.umt.edu.my
eISSN: 3009-0105
DOI: http://doi.org/10.46754/ps.2023.07.004

DO SEAFOOD CONSUMERS HAVE A HIGHER DIET QUALITY COMPARED TO NON-CONSUMERS? A CANADIAN PERSPECTIVE

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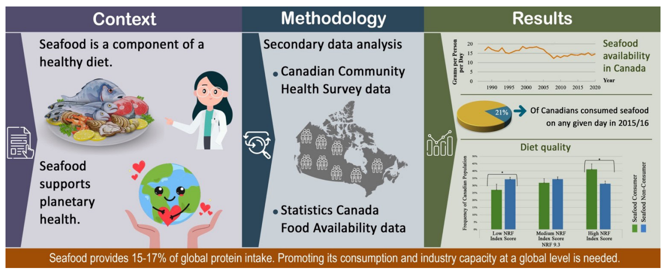
HIGHLIGHTS

- Seafood available for human consumption in Canada has been fairly consistent from 1990 to 2020, contributing to 8% of total protein foods available (2020), despite emerging dietary recommendations promoting the inclusion of moderate amounts of seafood in a healthy diet.
- Age and sex are statistically significant determinants of seafood consumption, such that being older and male increases the odds of being a seafood consumer.
- Immigrants to Canada have higher odds of being seafood consumers compared to Canadian-born individuals.
- Canadians residing in Western Canada have higher odds of being seafood consumers compared to individuals from Central Canada.
- Compared to non-consumers, seafood consumers have a superior diet quality, as determined by a higher nutrient-rich food (NRF) index score.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article History:
Received 20 October 2022
Submitted final draft 2 May 2023
Accepted 2 May 2023

Keywords:
Fish, shellfish, planetary health, nutrient density, nutrient-rich food index, national survey data, Canadian Community Health Survey.

ABSTRACT

Seafood represents a nutritious source of protein for many Canadians, including substantial amounts of omega-3 polyunsaturated fatty acids, vitamin D, vitamin B12, vitamin B6, and niacin. Many national and international dietary guidelines recommend regular consumption of seafood to support a healthy diet. The consumption of seafood continues to gain public attention due to its role in a healthy diet and its influence on environmental sustainability.

The aim of this analysis was to further our knowledge and understanding of the trends in the availability of seafood accessible for human consumption, the sociodemographic and socio-economic impact on consumption, and the associated health and nutritional impact of consumption in Canada. Statistics Canada food availability data and the Canadian Community Health Survey were used to assess our objectives. Food and nutrient intakes were calculated based on 24-hour dietary recall data. Overall, approximately 21% of Canadians reportedly consumed seafood on any given day in 2015/16. Higher odds of seafood consumption occurred in an older population, Canadians residing in Western Canada, and immigrants to Canada. Diet quality, measured using the nutrient-rich food index score, was significantly higher among seafood consumers compared to non-consumers. Further research should be completed to quantify the health effects of seafood consumption among Canadians.

Abbreviations

CCHS	Canadian Community Health Survey
CCHS-N	Canadian Community Health Survey-Nutrition
CAD	Canadian Dollars
DHA	Docosahexaenoic Acid
EPA	Eicosapentaenoic Acid
n-3 PUFA	Omega 3 Polyunsaturated Fatty Acid
NRF	Nutrient-Rich Food
PUMF	Public Use Microdata File

Introduction

Seafood, defined as fish (both marine and freshwater), molluscs, and crustaceans is an important part of a healthy, balanced diet (FAO of UN, 2021). The Lancet planetary health guidelines emphasize the inclusion of seafood in one's diet as a nutritional protein source supporting both human and environmental health (EAT-Lancet Commission, 2019). Additionally, seafood plays an important role in the Canadian economy, such that fisheries are among the top industries generating employment and gross domestic product in Canada (Ganter *et al.,* 2021). Yet, according to Hu and Chen's (2021) analysis of Canadian Community Health Survey (CCHS) data, the average Canadian population consumption rate of seafood was reported to be approximately 17% (16.36% in 2004 and 17.71% in 2015), and among Canadians consuming seafood, the mean portion size was approximately 36 kg/yr intake, which is equal to 6.2 kg per capita annual consumption or 16.97 g/d. To provide context, the Lancet planetary health guidelines recommend consuming 28 g of protein intake from fish daily, which accounts for 40 Kcal/d, based on a 2500-calorie diet (EAT-Lancet Commission, 2019). The current Canadian seafood consumption patterns equate to an average annual Canadian household expenditure of $274 CAD in 2019, accounting for 3% of total food expenditure (Statistics Canada, 2021). Fisheries and Oceans Canada estimates seafood consumption to increase by

9% by 2027 (Fisheries and Oceans Canada, 2018).

Seafood is a protein-rich and low-fat food source (except for oily fish, which provide a healthy source of fat), with many nutrients that are positively attributed to human health (Larsen *et al.,* 2011). For instance, some micronutrients such as omega-3 polyunsaturated fatty acids (n-3 PUFAs), vitamin D, selenium, iodine, zinc, and magnesium are more abundant in aquatic animals compared to other animal- or plant-based proteins (Hu & Chen, 2021). More specifically, one 75 g serving of seafood can provide up to 75% of one's recommended daily intake of n-3 PUFAs (75% docosahexaenoic acid [DHA], 26% eicosapentaenoic acid [EPA]), 18% of vitamin D, 19% of vitamin B12, 6% of niacin, 4% of vitamin B6, 2% of zinc, and 2% of magnesium (Hu & Chen, 2021). The Dietary Guidelines for Americans (2015–2020) recommend at least eight ounces of seafood (less for young children) per week based on a 2000-Kcalorie diet (HHS, 2021). Canada's 2019 Food Guide recommends choosing a variety of protein foods as part of a healthy diet while emphasizing choosing more healthy fats instead of saturated fats and suggesting seafood to contribute to 5-6% of daily protein intake (Health Canada, 2019; Hu & Chen, 2021). The previous version (2007) of Canada's Food Guide recommended at least two 75 g servings of seafood per week for adults and children who are 2 years of age or older (Health Canada, 2007).

The impact of seafood on the human diet and its beneficial health implications have been demonstrated in non-communicable diseases incidence as well as in overcoming micronutrient deficiencies (Larsen *et al.,* 2011; Rutzon, 2011; Kawarazuka & Bene, 2011; Troell *et al.,* 2019). Numerous studies have indicated that the addition of seafood to one's diet alters plasma lipid levels; for instance, plasma triglyceride, total cholesterol, and low-density lipoprotein were reduced while high-density lipoprotein levels were either unaffected or increased (Yuan *et al.,* 2001; Kawarazuka & Bene, 2011). Seafood is known for its high amount of DHA and EPA, which are linked to the prevention and protection against cardiovascular diseases (Larsen *et al.,* 2011). Moreover, a study suggested that middle-aged Chinese men who consumed at least one serving of seafood in a week had a 44% reduction in risk of fatal myocardial infarction in comparison with non-consumers (Yuan *et al.,* 2001). Further, it has previously been shown that increasing seafood consumption was associated with greater bone mineral density in women, especially those who consumed more than 250 g of seafood per week (Zalloua *et al.,* 2007). However, seafood consumption did not show consistent roles in reducing cancer incidence (Lovegrove *et al.,* 2015).

Hu and Chen (2021) laid the groundwork to understand seafood consumption trends in Canada and the associated impact on nutrient intake based on the most recent national nutrition survey data; however, a comprehensive understanding is still lacking on the nuances of seafood consumption in Canada. For instance, despite the beneficial nutrient contributions of seafood, there is no available literature reporting on the role it plays in overall diet quality among Canadians. Further, there is limited information available on how the patterns of seafood consumption impact the prevalence of chronic conditions in Canada. Therefore, in this study, we set out to advance available literature and our understanding of seafood consumption trends and the associated health and nutritional impact of seafood consumption in Canada. The objectives of this study were (i) to explore consumer availability of seafood in Canada over several decades; (ii) to explore the sociodemographic and socio-economic determinants of seafood consumption in Canada; (iii) to compare and assess the diet quality (via the Nutrient Rich Food [NRF] Index score) of seafood consumers and non-consumers at national and provincial levels; and (iv) to compare the prevalence of chronic conditions among seafood consumers and non-consumers.

Materials and Methods

Data Source and Analytical Sample

Objective (i) is based on Statistics Canada's food availability data which provides annual reports on the availability of food for consumption per person (Statistics Canada, 2022). The data presented in the food availability tables are extracted from administrative files and derived from other Statistics Canada surveys (Statistics Canada, 2022). 'Food availability' is defined as the amount of food physically present and available for human consumption (Statistics Canada, 2022). Food availability was calculated using the supply-disposition approach, such that the total disposition of food (not including domestic disappearances such as exports, livestock feed, and manufacturing uses) is subtracted by the sum of the total food supply (including imports, beginning stocks, and national production) and then, divided by the Canadian population to yield the per capita availability of certain foods (Statistics Canada, 2022).

Objectives (ii)-(iv) are based on the 2015/2016 version of Canadian Community Health Survey-Nutrition (CCHS-N) data from Statistics Canada's Public Use Microdata File (PUMF) Collection. The CCHS-N is a cross-sectional survey that relied on voluntary responses from the Canadian population. The target population of CCHS-N includes individuals who are aged 1 year and older, living in one of the 10 provinces while excluding individuals living on reserves or other Indigenous settlements, full-time members of the Canadian Forces, or the institutionalized population (Statistics Canada, 2019). Dietary data were collected using two 24-hour dietary recalls (Statistics Canada, 2019). For young children, varying levels of support were provided to complete the 24-hour recall; for instance, respondents aged 1 to 6 years underwent proxy interviews, respondents aged 6 to 12 years underwent interviews with parental guidance, and respondents greater than 12 years the non-proxy method was used (Statistics Canada, 2019). For the purposes of the current study, only the first 24-hour recall dietary recall was used.

A subset of the CCHS-N PUMF data was used for the purposes of the current study, objectives (ii)-(iv), and is referred to as the analytical sample. The analytical sample excluded individuals who were currently breastfeeding had given birth within the last 5 years did not report any food intake in the 24-hour dietary recall, or reported a calorie intake outside of 200-8,000 kcal/d. The analytical sample included 20,487 respondents, and with consideration of sample weights and bootstrap weights, the sample represented 32,787,075 Canadians and is generalizable to Canadians residing in one of the 10 provinces.

Variable Definitions

Statistics Canada Food Availability Data

To investigate protein food availability in Canada, several protein food groups were defined. The seafood protein group included food availability data on all aquatic animals such as marine fish, freshwater fish, shellfish, and processed fish. For the purposes of comparison, additional protein groups were derived such as plant-based proteins (baked/canned/dried beans, canned/fresh/frozen/dried peas, lima beans, peanuts, tree nuts), poultry (chicken, stewing hen, turkey), red meat (beef, mutton, lamb, veal), eggs, pork, and organ meats.

Statistics Canada CCHS-N Data

Several variables were derived from investigating the research questions such as seafood consumption variables, the NRF Index, and the occurrence of any chronic conditions. First, seafood consumers were defined by using 24-hour dietary recall data such that any individual who reported consumption of shellfish, high-fat fish (6% total fat), or low-fat fish (< 6% total fat) during the first 24-hour dietary recall. Seafood consumption was defined as a binary variable, such that Canadians were classified as consumers and non-consumers. Additionally, Canadians classified as seafood consumers were further classified into consumption tertiles or consumption groups. These consumption groups represented three equal groups from the entire sample population of seafood consumers and were defined as low (50 g/d), medium (51-115 g/d), and high (≥ 116 g/d) seafood consumption; as a reference, according to the 2007 version of the Canadian Food Guide one serving of seafood is 75 g (Health Canada, 2007). Although these consumption groups were defined by equally splitting the sample population, when crossing the consumption groups with other variables such as age or sex, we can formulate a deeper understanding of how these factors interact. Second, the NRF index variable was computed from an adapted version of the NRF 9.3 index, a validated formal measure to assess overall diet quality (Drewnowski, 2010). The NRF index variable was derived by subtracting the sum percentage of the daily values of nine nutrients to encourage (protein, fibre, vitamin A, vitamin C, vitamin D, calcium, iron, magnesium, and potassium) by the maximum recommended values for three nutrients to limit (saturated fat, total sugar, and sodium) (Drewnowski, 2010). Higher NRF index scores (maximum score 900) indicate the diet is nutrient-rich and is associated with positive outcomes (Drewnowki, 2010). Similarly, to seafood consumption groups, NRF index tertiles were derived from investigating the frequency of the population that has a low (NRF score 366), medium (NRF score 367-478), or high (NRF score ≥ 479) diet quality based on other factors. Finally, the total chronic condition variable was defined by whether the respondent answered 'yes' to at least one of the following chronic conditions – type 2 diabetes (T2D), hypertension, heart disease, cancer, or osteoporosis.

Statistical Analysis

Statistical analysis was completed using SAS software, version 9.4. Statistics Canada's recommended sample weights and bootstrap weights were applied to all analyses to yield population-level estimates. Descriptive statistics were computed and summarized according to seafood consumption variables. Continuous variables were computed as weighted means, whereas categorical variables were computed as weighted frequencies. For all variables, statistics were reported as the mean or frequency with the standard error and 95% confidence interval. Statistical significance was determined via the confidence interval approach, recommended by Statistics Canada for CCHS-N data analysis, such that if the 95% confidence intervals overlapped, the parameters were statistically equivalent; alternatively, if the 95% confidence intervals did not overlap, the parameters were determined to be statistically different.

A logistic regression model was developed with the intent of understanding potential sociodemographic determinants of seafood consumption among the Canadian population. The binary outcome variable represented seafood consumers and non-consumers, and predictor variables included sociodemographic factors such as age, sex, area of residence, and food security status. All necessary assumptions for logistic regression modeling were tested for and met. Equation 1, indicated below was used as a template for the regression model.

Equation 1:

$$Ln(p/(1\text{-}p)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_m X_m + \epsilon.$$

Results and Discussion

Seafood Availability in Canada

Figure 1 depicts Canadian protein food availability trends from 1960 to 2020. Food availability trends help us understand the food market and consumer food demands. When seafood availability was reported, from 1988 to 2020, the lowest availability was in 2008, with 12.24 g available per person per day, and the highest seafood availability was in 1999, with 18.62 g available per person per day. Seafood falls among the least available protein foods in Canada, along with organ meat and plant-based proteins. Further, when investigating the overall percent distribution of different protein foods and their availability in Canada, seafood availability decreased by 3% from 1990 to 2020, as seen in Figure 2. This decrease in availability was common among most protein foods under study (such as red meat, pork, organ meat, and plant-based proteins) to account for the notable increase in poultry availability from 17% to 31%.

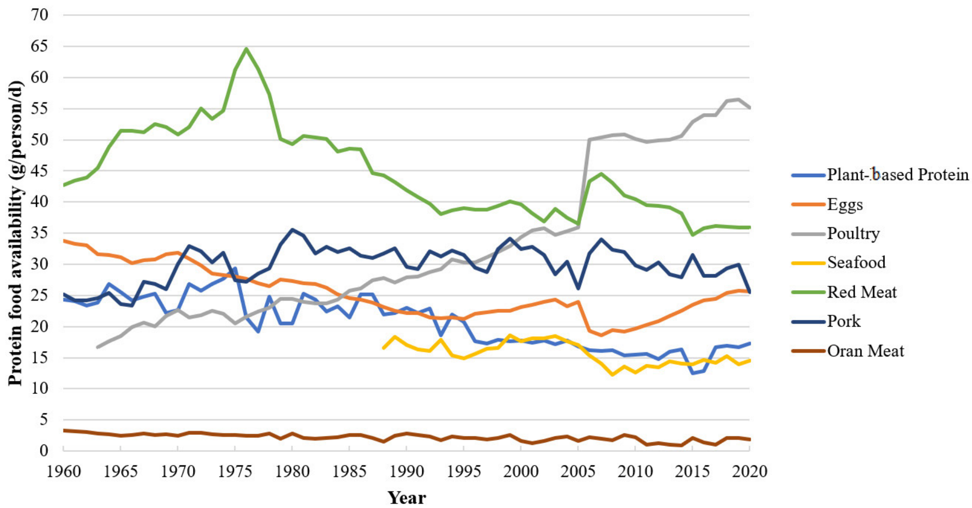


Figure 1: Protein food availability (adjusted for loss) in Canada from 1960 to 2020
Data source: Statistics Canada, Table 32-10-0054-01 (Food available in Canada). Plant-based proteins include baked/canned/dried beans, canned/fresh/frozen/dried peas, lima beans, peanuts, and tree nuts. Poultry includes chicken, stewing hen, and turkey. Seafood includes sea fish, freshwater fish, shellfish, and processed fish. Red meat includes beef, mutton, lamb, and veal

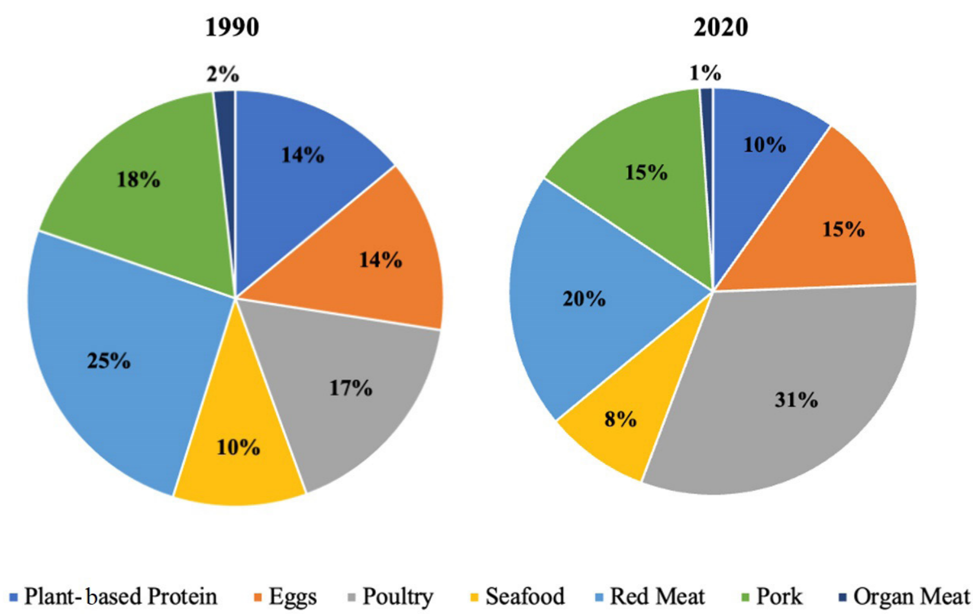


Figure 2: Percent contribution of protein food availability (adjusted for loss) in Canada in 1990 and 2020
Data source: Statistics Canada, Table 32-10-0054-01 (Food available in Canada). Plant-based proteins include baked/canned/dried beans, canned/fresh/frozen/dried peas, lima beans, peanuts, and tree nuts. Poultry includes chicken, stewing hen, and turkey. Seafood includes sea fish, freshwater fish, shellfish, and processed fish. Red meat includes beef, mutton, lamb, and veal

As mentioned, food availability trends reflect consumer food demands, and we can use these trends to extrapolate the average consumption rates in the country. Based on our seafood availability analysis, there were approximately 13.99 g of seafood available per Canadian per day in 2015, and Hu and Chen (2021) found a mean consumption rate among consumers of 16.97 g/d in 2015. Considering that 20.83% of Canadians consume seafood, only 25.23% of seafood available for human consumption is being consumed. However, there are many other factors that should be considered such as accounting for domestic disappearance values and food waste statistics. When accounting for food waste at 31.21% (based on average fish waste from 1961 to 2009), the percent of seafood available for human consumption that is actually being consumed increases to 80.96% (Abdulla *et al.,* 2013). This equates to approximately a 19% discrepancy between food availability data and mean consumption rates; however, this discrepancy could be explained, in part, due to seafood's naturally shorter shelf-life, domestic disappearance, and limitations in estimating mean consumption from a single 24-hour dietary recall in cross-sectional data.

Comparing the percent contribution of seafood to total protein intake, Auclair and Burgos (2020) found that seafood contributes to 5% of Canadians' total protein intake, based on 2015 CCHS-N data. This is comparable to the 8% of seafood available for Canadian consumption in 2020. However, once again, there are other factors to consider such as those mentioned in the above paragraph as well as the variation in the reporting year the data was based on and what foods were considered to contribute to total protein intake. In our food availability analysis, we considered red meat, pork, organ meat, poultry, eggs, plant-based proteins, and seafood to contribute to total protein intake, whereas Auclair and Burgos (2020) considered red/processed meats, poultry, eggs, dairy, nuts/seeds/legumes, vegetables/fruit, cereals/bread/grains, and seafood to contribute to total protein intake. Nevertheless, in both instances, seafood had a minimal contribution to total protein food availability and intake. Considering a global perspective, seafood obtained from aquaculture or capture fisheries contributes to 15-17% of animal-sourced protein at a global level (Boyd *et al.,* 2022). Several countries in Southeast Asia (Cambodia, Myanmar, Malaysia, Indonesia) and select countries in Northern Europe (Norway, Iceland, Greenland) and the Mediterranean (Spain, Portugal) have the highest contribution of seafood to protein intake at great than 10 g/capita/d (Troell *et al.,* 2019). Recent projects suggested stagnation of capture fisheries and continued growth in aquaculture, supporting a more sustainable approach with introductions to new sustainable feed options (Troell *et al.,* 2019). The lower consumption in Canada and at a global level could be explained by the perceived difficulty in preparing seafood, its limited shelf life, the risk of supporting unsustainable fisheries, and the cost of aquaculture or capture fisheries operations. Whereas the higher consumption of seafood in select countries in Southeast Asia, Northern Europe, and the Mediterranean is due in part to traditional dietary patterns and in part due to the rapid growth of the aquaculture industry in some of these countries (Naylor *et al.,* 2021).

Determinants of Seafood Consumption in Canada

Table 1 outlines the sociodemographic and socio-economic determinants for seafood consumption in Canada. Approximately 21% of Canadians reportedly consumed seafood on any given day in 2015/16 at a mean consumption rate of 16.51 g. This frequency differs from the 17% Hu and Chen (2021) found; however, this is likely due to the different formats of CCHS-N data 2015/16 used. Of the determinants under study, statistically significant differences in age and sex of Canadians were found with seafood consumption. The mean age for seafood consumers was significantly higher (44.89 ± 0.54) than the mean age for non-consumers (40.89 ± 0.25). Table 2 outlines the sociodemographic and socio-economic determinants for low, medium, and high seafood consumption patterns in Canada. When investigating these consumption groups, age remained a significant determinant. For instance, a significantly higher proportion of children aged 1-8 years of age (13.38% ± 2.55) were classified into the lowest consumption group, compared to the medium consumption group (5.54% ± 1.09), indicating younger children are more likely to consume less, or smaller portions of seafood. A similar pattern exists for Canadians aged 9-18 years. Moreover, a significantly higher proportion of males fell within the highest consumption group of seafood (64.42% ± 3.20), compared to the lowest consumption group (40.85% ± 5.31). The opposite was observed in female seafood consumers, such that a significantly lower proportion of females fell within the highest consumption group (35.59% ± 3.20), compared to the lowest consumption group (59.15% ± 5.31).

Table 1: Sociodemographic and socioeconomic factors across seafood consumers and non-consumers in the Canadian population[1]

	Seafood Consumer n=5,652,215	**Seafood Non-consumer n=27,134,860**
Mean age ± SE	44.89 ± 0.54*	40.89 ± 0.25*
Sex (% male) ± SE	50.45 ± 2.43	52.09 ± 0.56
Food security (% food secure) ± SE	94.35 ± 1.81	91.38 ± 0.58
Marital status (% married) ± SE	46.39 ± 7.18	40.58 ± 3.28
Immigration status (% immigrant) ± SE	32.38 ± 6.05	21.70 ± 3.80
Recent immigration status (% recent) ± SE	25.01 ± 2.52	28.67 ± 3.42
Household education (% post-secondary education) ± SE	78.14 ± 2.75	77.17 ± 0.80
Household income – % Decile 1, 2 ± SE	20.96 ± 1.46	19.35 ± 0.66
– % Decile 3, 4 ± SE	19.53 ± 2.28	20.57 ± 1.03
– % Decile 5, 6 ± SE	19.31 ± 1.96	20.65 ± 1.76
– % Decile 7, 8 ± SE	20.12 ± 2.00	19.39 ± 0.71
– % Decile 9, 10 ± SE	20.09 ± 2.31	20.04 ± 2.81
Area of Canada – % Atlantic Canada ± SE	5.62 ± 0.35	6.93 ± 0.10
– % Central Canada ± SE	63.49 ± 1.26	61.80 ± 0.32
– % Prairie provinces ± SE	14.53 ± 0.92	18.82 ± 0.22
– % Western Canada ± SE	16.37 ± 1.21	12.46 ± 0.23

Data source: 2015/2016 Canadian Community Health Survey PUMF. *Statistical significance as defined by a 95% confidence interval approach. [1]All data is weighted and bootstrapped to obtain estimates at the Canadian population level

Table 2: Sociodemographic and socioeconomic factors across low, medium, and seafood consumption patterns in the Canadian population[1]

	Low Seafood Consumption n=1,905,195	**Medium Seafood Consumption n=1,878,593**	**High Seafood Consumption n=1,868,427**
Age – % 1-8 years ± SE	13.38 ± 2.55*	5.54 ± 1.09*	-
– % 9-18 years ± SE	8.50 ± 1.02*	9.39 ± 2.04	5.78 ± 0.80*
– % 19-50 years ± SE	39.33 ± 4.10	36.67 ± 4.51	45.26 ± 4.40
– % 51+ years ± SE	38.79 ± 5.80	48.39 ± 3.01	45.88 ± 4.45
Sex (% male) ± SE	40.85 ± 5.31*	46.30 ± 4.06*	64.42 ± 3.20**
Food security (% food secure) ± SE	96.31 ± 2.06	92.72 ± 2.58	93.98 ± 2.04
Marital status (% married) ± SE	42.78 ± 7.47	47.98 ±6.46	48.47 ± 8.43
Immigration status (% immigrant) ± SE	33.18 ± 3.25	32.91 ±7.27	31.03 ± 9.09
Recent immigration status (% recent) ± SE	27.30 ± 3.91	28.68 ± 6.51	18.64 ± 4.86
Household education (% post-secondary education) ± SE	80.61 ± 3.45	77.58 ± 5.06	76.18 ± 5.78
Household income – % Decile 1, 2 ± SE	22.08 ± 2.62	20.57 ± 2.37	20.21 ± 3.10
– % Decile 3, 4 ± SE	22.27 ± 2.56	19.40 ± 2.79	16.87 ± 3.33
– % Decile 5, 6 ± SE	14.95 ± 4.67	22.73 ± 2.84	20.30 ± 3.02
– % Decile 7, 8 ± SE	23.11 ± 3.98	18.13 ± 2.41	19.06 ± 3.11
– % Decile 9, 10 ± SE	17.60 ± 1.99	19.17 ± 2.26	23.56 ± 4.31
Area of Canada – % Atlantic Canada ± SE	3.99 ± 1.32	5.95 ± 0.89	6.95 ± 0.64
– % Central Canada ± SE	64.91 ± 2.47	60.47 ± 4.80	64.82 ± 4.06
– % Prairie provinces ± SE	13.40 ± 2.48	16.35 ± 2.24	13.38 ± 1.74
– % Western Canada ± SE	17.71 ± 3.01	16.96 ± 2.60	14.40 ± 3.33

Data source: 2015/2016 Canadian Community Health Survey PUMF. *Statistical significance as defined by a 95% confidence interval approach. – Frequency is 5%. [1]All data is weighted and bootstrapped to obtain estimates at the Canadian population level

The regression model, based on Equation 1, evaluated the association between seafood consumers and non-consumers as the outcome variable with sociodemographic determinants. The model had a weighted population of 19,396 and an R^2 value of 0.0344 and included sex, age, food security status, marital status, immigration status, and area of residence. The regression analysis found age, food security status, immigration status, and area of residence to be significant predictors of seafood consumption at $p<0.05$. The directional influence of predictor variables on the consumption of seafood is presented in Figure 3. For example, odds ratio analysis indicates the odds of being a seafood consumer were higher among respondents greater than 51 years of age (OR=1.14), those living in Western Canada (OR=1.21), or immigrants to Canada (OR=1.69).

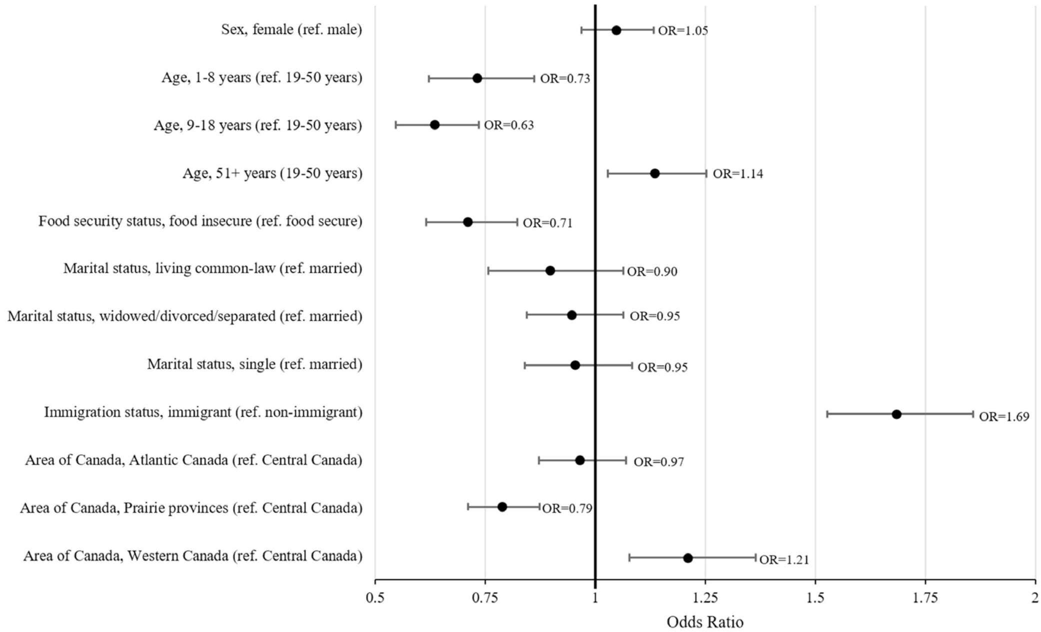


Figure 3: Factors associated with the odds of seafood consumption in the Canadian population
Data source: 2015/2016 Canadian Community Health Survey PUMF, all data is weighted and bootstrapped to obtain estimates at the Canadian population level

Our findings added to that of Hu and Chen (2021). We found immigrants were more likely to be seafood consumers compared to non-immigrants, and this finding emphasizes the importance of culture and traditional diets in our food choices. Based on 2021 data, Canadian immigrants were most commonly from India, China, Philippines, Nigeria, France, and the USA; and countries that have the highest estimated seafood consumption per capita are Japan, China, Indonesia, the European Union, the USA, and India (Guillen *et al.,* 2019; Statista Research Department, 2022). Japan had the highest consumption rate at almost 60 kg per capita, closely followed by China with almost 50 kg per capita (Guillen *et al.,* 2019). Traditional Japanese and Chinese dietary patterns emphasize the inclusion of seafood as a healthy protein source (FAO of US, 2022). For example, a traditional Japanese diet is characterized by high consumption of fish and soybean products and low consumption of animal meats (Gabriel *et al.,* 2018). Diet plays an important role in our health, and seafood consumption has been implicated in improved health metrics. The Healthy Immigrant Effect finds immigrants to be healthier than the Canadian-born population, but their health status diminishes over their time spent in Canada; this deterioration is due to many factors, including transitions in their dietary patterns (Sanou *et al.,* 2014). It could be postulated that the higher odds of immigrants consuming seafood, compared to Canadian-born individuals plays a role in the Healthy Immigrant Effect and that over time, immigrants adapt to a Canadian or Western-style diet with reduced odds of consuming seafood.

Our analysis found Canadians residing in Western Canada (British Columbia) had increased odds of consuming seafood compared to their peers residing in Central Canada (Ontario, Quebec). It could be hypothesized that this is due to aspects of coastal living and the geographical proximity to the ocean; however, proximity to inland lakes and freshwater fish sourced from these lakes should not be discredited. Globally, there are trends in marine and freshwater fish consumption based on country; for example, China and India have a higher consumption of freshwater fish, whereas Spain and France have a higher consumption of marine fish (Naylor *et al.,* 2021). Analysis of the distribution of consumption rates of freshwater versus marine fish has not been done within Canada.

Diet Quality and Seafood Consumption in Canada

Figure 4 illustrates the frequency of Canadians falling in the low, medium, and high NRF index groups based on seafood consumption status. Most notably, seafood consumers have a significantly higher proportion of their population fall within the high NRF index group compared to non-consumers, suggesting that Canadians who consume seafood have a superior diet quality compared to non-consumers. Consequently, seafood consumers also have a significantly lower proportion of their population fall within the low NRF index group compared to non-consumers, once again suggesting a superior diet quality among Canadians who consume seafood. A similar pattern can also be observed when investigating the mean NRF index score, such that seafood consumers have a significantly higher mean NRF index score (450.17 ± 4.70) compared to non-consumers (412.23 ± 2.39).

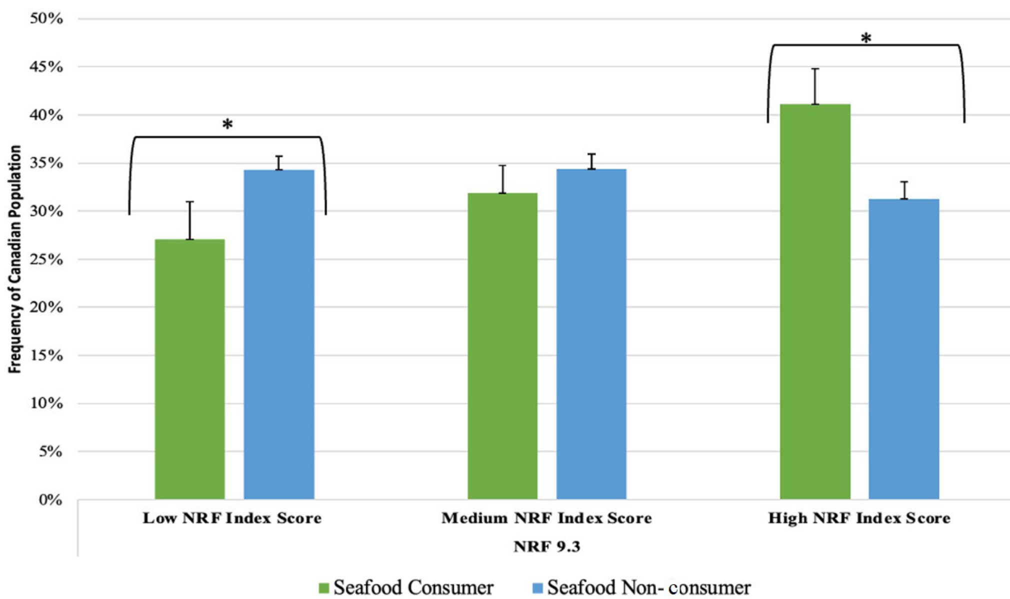


Figure 4: NRF index levels among seafood consumers and non-consumers in the Canadian population

Data source: 2015/2016 Canadian Community Health Survey PUMF, all data is weighted and bootstrapped to obtain estimates at the Canadian population level. *Statistical significance as defined by a 95% confidence interval approach. A low NRF index score is defined as an NRF score 366, a medium NRF score is defined as an NRF score of 367-478, and a high NRF score index score is defined as ≥ 479

Figure 5 depicts the distribution of seafood intake across Canadian provinces and compares it to the mean NRF index score of each province. Canadians residing in British Columbia represent the highest prevalence of seafood consumers at 21.5%, and Canadians residing in New Brunswick represent the lowest prevalence at 12.68%. Regarding the mean intake of seafood, among consumers, Saskatchewan and British Columbia had the highest mean intake of 18.80 g/d and 18.78 g/d, respectively. It is interesting to note the province of Saskatchewan, a landlocked province, had the highest mean intake; as mentioned in Determinants of Seafood Consumption in Canada section, the consumption of freshwater fish and the influence of lake fishing should not be discredited. In alignment with trends at the national level, provincial trends suggest seafood consumption plays a role in diet quality, as shown through mean NRF index scores. For instance, in British Columbia, 21.5% of their residents identify as seafood consumers, and on average consume 18.78 g/d, and at a provincial level, they have the highest mean NRF index score of 429. Whereas, in Manitoba, only 12.75% of their residents identify as being seafood consumers, and on average, consume only 12.69 g/d, and at a provincial level, have one of the lowest mean NRF index scores at 391. These two provinces have statistically different mean NRF index scores and prevalence of seafood consumers. We could extrapolate that both the prevalence of seafood-consuming residents and their mean seafood intake impact a province's mean NRF index score; however, we must also consider the many other factors such as household income, education, food security status, and various lifestyle factors, impact the mean NRF index scores.

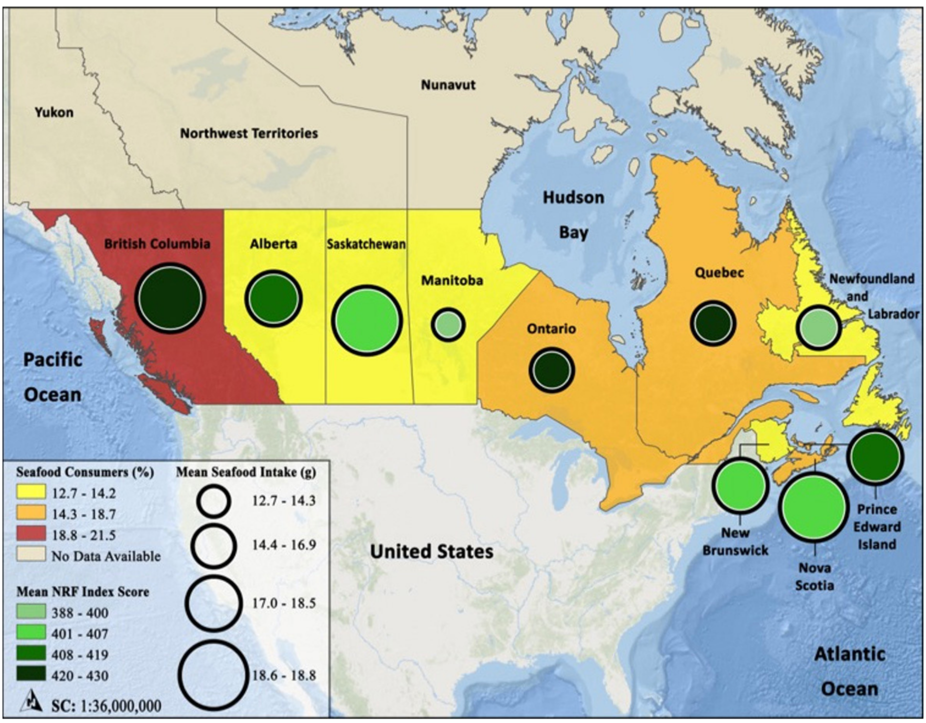


Figure 5: Seafood consumption geo-mapping - distribution of the frequency of seafood consumers, their mean intake, and their diet quality (average NRF index score) across Canadian provinces

Data source: 2015/2016 Canadian Community Health Survey PUMF, all data is weighted and bootstrapped to obtain estimates at the Canadian population level

The superior diet quality found among seafood consumers reinforces numerous national dietary food guidelines that have come out in the past decade. For instance, Northern European countries such as Denmark, Estonia, Finland, Norway, and Sweden all place importance on choosing fish more often over other sources of animal meat and suggest eating seafood anywhere from two to three times per week (FAO of US, 2022). Recommendations for increased seafood consumption are also found in international guidelines, such as the Lancet planetary health guidelines mentioned in Introduction, which recommend 28 g of fish to be consumed per day, which falls second to recommendations for poultry at 29 g/d among animal-based proteins (EAT-Lancet Commission, 2019). These dietary guidelines support the important role of regular seafood consumption in one's diet for optimal diet quality.

Two factors that should not be overlooked when assessing the nutritional contributions of seafood to overall diet quality are the species of seafood, and the cooking method used. For instance, the amount of DHA, iron, phosphorus, and vitamin A vary greatly depending on the species of fish. An example of this can be seen when comparing a 75 g serving of Atlantic salmon to canned sardines, where there is 1.09 g and 0.38 g of DHA, 0.3 g and 2.2 g of iron, 189 g and 367 g of phosphorus, and 11 RAE and 24 RAE of vitamin A, respectively (Health Canada, 2010). Further, the methods used to cook seafood impact the nutritional contributions of the dish. Undeniably, preparing seafood by frying in oil, compared to baking would result in a dish with increased calories and 'less healthy fats' such as saturated and trans fats.

Prevalence of Chronic Conditions and Seafood Consumption in Canada

Table 3 outlines the prevalence of chronic conditions among seafood consumers and non-consumers in Canada. Our analysis found no statistically significant associations between seafood consumption and the prevalence of overweight or obesity, T2D, hypertension, heart disease, cancer, or osteoporosis. Moreover, the broader total chronic conditions variable, which evaluates respondents who reported having at least one of the aforementioned chronic conditions also did not have statistically different proportions based on seafood consumption.

We speculate our insignificant findings may be due to the relatively small sample size of seafood consumers in the CCHS-N PUMF data as well as the chronic conditions reported in the data. A recent umbrella review investigating fish consumption and the risk of chronic conditions found moderate quality evidence suggesting a dose-dependent relationship between increased fish consumption and lower risks of all-cause mortality, cardiovascular mortality, coronary heart disease, myocardial infarction, stroke, heart failure, depression, and liver cancer (Jayedi & Shab-Bidar, 2020). It is reasonable to deduce the observed beneficial effects of fish consumption on cardiovascular diseases are due to the high content of n-3 PUFAs in select aquatic protein sources. N-3 PUFAs have favorable effects on inflammation, oxidative stress, and platelet aggregation, as well as modest blood pressure-lowering properties (Jayedi & Shab-Bidar, 2020). Considering the findings from Jayedi and Shab-Bidar (2020), it is reasonable to presume our study did not yield significant results due to the lack of specificity of the heart disease definition in CCHS-N PUMF data.

Conclusion

Approximately 21% of Canadians reported consuming seafood based on their CCHS-N 24-hour dietary recall in 2015/2016, and the availability of seafood in Canada remained fairly stable, from 16.59 g available per person/d in 1990 to 14.57 g available per person/d in 2020. Our analysis determined that age and sex are statistically significant determinants of seafood consumption, such that consumers were often older, and males reportedly consumed greater volumes. The odds of being a seafood consumer were significantly greater among Canadians 51 years of age and older living in Western Canada and those who were classified as immigrants to

Table 3: Prevalence of chronic conditions among seafood consumers in the Canadian population[1]

	Seafood Consumer n=5,652,215	Seafood Non-consumer n=27,134,860
Youth BMI - % thin/normal ± SE	75.14 ± 3.91	68.43 ± 1.05
- % overweight ± SE	17.55 ± 3.23	18.99 ± 1.18
- % obese ± SE	7.31 ± 2.32	12.58 ± 1.08
Adult BMI - % underweight/normal ± SE	36.99 ± 2.72	38.17 ± 1.21
- % overweight ± SE	38.14 ± 2.21	34.57 ± 1.11
- % obese ± SE	24.87 ± 2.73	27.26 ± 0.99
Type 2 diabetes (% yes) ± SE	7.43 ± 0.84	7.11 ± 1.18
Hypertension (% yes) ± SE	20.48 ± 1.50	20.94 ± 0.64
Heart disease (% yes) ± SE	-	5.29 ± 0.35
Cancer (% yes) ± SE	-	-
Osteoporosis (% yes) ± SE	8.32 ± 1.07	11.21 ± 1.42
Total chronic condition (% yes) ± SE	48.16 ± 2.17	55.59 ± 1.84

Data source: 2015/2016 Canadian Community Health Survey PUMF. *Statistical significance as defined by a 95% confidence interval approach. – Frequency is 5%. [1]All data is weighted and bootstrapped to obtain estimates at the Canadian population level

Canada. Compared to non-consumers, seafood consumers were also identified as having superior diet quality, with a greater proportion of their population classifying in the highest NRF index score group and a lower proportion classifying in the lowest NRF index score group. Figure 6 depicts our main findings and suggestions for future research.

Further research needs to be completed to develop a more comprehensive understanding of the role of seafood in our diet and how it affects the health and prevalence of chronic conditions among Canadians and at a global level. When investigating the potential relationship between seafood consumption and chronic conditions, special consideration should be taken to consider conditions that are associated with n-3 PUFAs such as cardiovascular conditions, as well as the types of seafood and the cooking methods used. Investigation into how knowledge, attitudes, and perceptions of seafood impact Canadians' consumption patterns should be considered. In regard to policy and practice, our findings suggest many Canadians do not consume seafood, although it contributes to a healthy diet; therefore, dieticians should continue to support the inclusion and promotion of seafood in healthy diets. Further work at both the policy and practice levels should be completed to promote the consumption of seafood in Canada. Canada has substantial access to both freshwater and marine fish, as the country touches both the Pacific and Atlantic Oceans and is home to the most lakes in the world. However, approximately only 1 in 5 Canadians consumes seafood, and their mean intake is less than the values recommended by the Lancet Planetary Health guidelines. Therefore, we believe it is important to emphasize the need for health promotion initiatives to support the increased intake of seafood among Canadians. Possible health promotion initiatives may wish to look to countries that have a higher consumption of seafood such as countries in Southeast Asia, Japan, Norway, or the Mediterranean to facilitate increased seafood intake.

Strengths and Limitations

The use of CCHS-N data should be viewed as a strength as it contains nationally representative information on nutrition, health, and social factors. With the use of this data, implausible reporting of nutrient intakes was identified during the beginning stages of analysis and removed to avoid the effect of outliers. Additionally, this analysis is built on Hu and Chen's (2021) work, helping to contribute to a comprehensive understanding of seafood consumption in Canada through a diet quality lens. Irrespective of the strengths, the limitations should be acknowledged. This analysis is based on the use of cross-sectional data; therefore, no causal inferences can be drawn. Further, seafood consumption patterns were derived based on one 24-hour dietary recall, which may not accurately represent the totality of one's sustained diet. The regression model (based on Equation 1) was developed to investigate the determinants of seafood consumption; however,

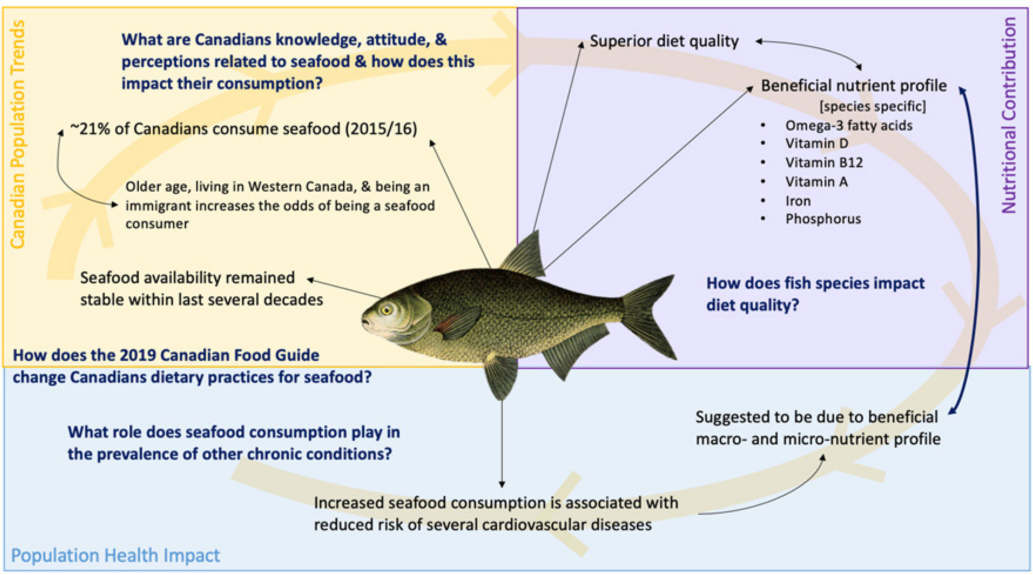


Figure 6: Visual summary of significant findings of our analysis with mention of avenues for future research

the model did not account for all factors related to seafood consumption due to the nature of the CCHS-N dataset, and therefore, the independent variables did not explain for much of the variation in the outcome. We recommend a logistic regression model to be completed using a different dataset to allow for consideration of additional sociodemographic and socio-economic determinants of seafood consumption. Finally, this analysis is based on 2015/2016 data and may not accurately represent the current trends of Canadian seafood consumption as social popularity, environmental reasons, and changes to national dietary guidelines may have impacted Canadian's viewpoints and consumption patterns of seafood since halfway through the second decade of the 21st century.

Acknowledgements

We wish to acknowledge our graphical designer, Mahla Nava for her assistance in the development of the graphics presented in this manuscript.

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