CHAPTER 4

Diet, Metabolic Health and Food Insecurity

Sentinel North
UNIVERSITÉ LAVAL

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In the context of accelerating climate change and socioeconomic development in the Arctic and Subarctic, the Sentinel North research program at Université Laval helps generate the knowledge needed to improve our understanding of the changing northern environment and its impact on humans and their health. The program fosters the convergence of expertise in the engineering, natural, social and health sciences to catalyze scientific discovery and technological innovation in support of sustainable health and development in the North.

This compendium presents a selection of results from the Sentinel North research program, from its beginning in 2017 through to the end of its first phase in 2022. The results are highlights from innovative research projects and original peer-reviewed publications, which have been integrated into five interdisciplinary chapters addressing major northern issues. Notwithstanding the scale and complexity of these issues, each chapter of the compendium aims to provide new insights through the process of integration, and fill fundamental gaps in our knowledge of the changing North.

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Shedding Light on the Connections between Diet, Metabolic Health and Food Insecurity in the North

Introduction

The interconnection between nutrition, human health and the environment has been embedded in the knowledge systems and cultural practices of Indigenous Peoples for thousands of years. Country food hunted, fished, and gathered from the land is a pillar of Inuit health (ITK, 2014). However, dietary transition is very rapid and the rates of food insecurity are alarming, and both have important consequences for health and well-being in Arctic communities (Egeland et al., 2011). In Inuit Nunangat, 76% of Inuit aged 15 and over reported experiencing food insecurity (ITK, 2021). A disparity in access to water services has also been noted across the Arctic, contributing to water insecurity (Sohns et al., 2019). Access to safely managed drinking water services and nutritious food remains challenging for millions of people living in the circumpolar Arctic (Cassivi et al., 2023).

Country foods significantly contribute to the nutrition, health, and food security of Canadian Inuit communities (Gagné et al., 2012; Little et al., 2021). They represent important sources of protein, vitamins, and minerals (Allaire et al., 2021b). Despite this key role, the ongoing effects of colonization, climate change, changes in food preferences, socio-economic challenges and concerns about contaminant exposure lead to a rapid dietary transition in these communities and threaten their food security and sovereignty (Little et al., 2021). Time-honoured food hunting and harvesting practices are increasingly being replaced by diets consisting of store-bought, nutrient-poor market foods (Furgal et al., 2021). Unhealthy diets, embodied by a western diet that is high in saturated fats, sugar, and processed foods, is the leading modifiable risk factor associated with mortality and the second leading risk factor for disability in Canada (Bacon et al., 2019). As western dietary patterns become more prevalent in the Canadian Arctic, health concerns such as obesity, diabetes, and cardiometabolic disease are on the rise (Allaire et al., 2021a). Thus, the association between diet and disease becomes increasingly crucial to understand, especially for Inuit population.

Advances in technology have allowed for a more in-depth understanding of the tangible link between dietary practices and disease. Specifically, two complex and interconnected systems have been identified in the control of energy metabolism and in metabolic disorders (Iannotti & Di Marzo, 2021). The gut microbiome, an ecosystem of microorganisms dictated by environmental factors such as diet and drugs, plays a crucial role in many aspects of human health, including immunity, metabolism and behaviour (Valdes et al., 2018). The endocannabinoid system is comprised of cannabinoid receptors, endocannabinoids and the enzymes responsible for their synthesis and degradation (Lu & MacKie, 2016), together known as the endocannabinoidome. The endocannabinoidome plays a central role in regulating a large variety of processes, including metabolism, appetite and digestion, inflammation, and neuromodulation. Both systems are heavily influenced by diet and mediate many dietary implications for health including communication along the gut-brain axis.

Obesogenic high-fat diets enhance endocannabinoid levels, both in the brain and peripheral tissues (Forte et al., 2020), thus modulating gut-derived signal transduction to the brain through various biomolecules. These biomolecules impact energy regulation and are involved in the development of neuroinflammation, which can subsequently alter behaviours. Thus, dietary changes control the endocannabinoidome and its bidirectional relationships with the gut microbiome, which regulates not only gastrointestinal metabolism but also brain function (Choi et al., 2020b).

A deeper understanding of how gut microbiota respond to poor dietary conditions is possible through the advent of predictive tools and biomarkers. Rapid and efficient disease diagnosis within the medical field is challenging, especially in remote areas (Azzi, 2019). Current gut microbiota analysis is mainly based on sequencing technologies to determine microbial composition and gene expression. The development of new tools and model organisms to allow a more in-depth investigation of microbiome-derived molecules as well as identification of early molecular biomarkers that are relevant to cardiometabolic disease pathogenesis is vital (Anhê et al., 2019, 2018; Cornuault et al., 2022).

Remote northern communities also lack access to safely managed drinking water services, stemming from poor water quality and insufficient water quantities. Culturally appropriate health-based interventions are necessary to ensure inclusive water services and to achieve the Sustainable Development Goal (SDG) targets for universal access to water (Cassivi et al., 2023).

This chapter brings together results from Sentinel North program that are deepening our understanding of the positive impacts of country food on the intestinal microbiota. It also discusses the links between diet and chronic diseases and the implications at different levels, from food environments to the molecular level. Finally, it sheds light on culturally adapted initiatives that tackle food and water security issues in collaboration with Northern communities. Collectively, these advances can inform research and action to prevent disease development linked to diet, improve nutritional health and ensure inclusive water services.

KEY WORDS:

Traditional food, Western diet, Gut microbiome, Gut-brain axis, Metabolic health, Endocannabinoidome, Food environment, Water security

1. The Benefits of Omega-3

Selected research highlights

The traditional Inuit diet is rich in polyunsaturated fatty acids from the omega-3 family, particularly due to frequent fish consumption. The health benefits of omega-3 are increasingly recognized both for the general population and the Inuit.

1.1 In a population with non-pathological eating behaviours, a study found that plasma levels of an omega-3 derivative (2-monoacyl-glycerol) were positively associated with intuitive eating behaviours, i.e., eating behaviours based on physiological signals of hunger and satiety. Research is ongoing to better understand the involvement of these bioactive lipids in regulating eating behaviours and to develop new nutritional and pharmacological strategies (Rochefort et al., 2021).

1.2 The consumption of fish oil, a rich source of omega-3 polyunsaturated fatty acids, combined with cannabidiol (CBD) produced a significant anti-inflammatory effect in colitis mice models. Moreover, fish oil and CBD used separately or in combination affected the gut microbiota of mice. These results highlight the potential of using the combination of low doses of fish oil and CBD for treating inflammatory bowel diseases (Silvestri et al., 2020).

1.3 Using a human gut simulator, a research team demonstrated that consumption of omega-3-rich fish oil supplements can modulate the composition of microbiota based on the gut region. Furthermore, consumption of these supplements was associated with a remarkable blooming of *Akkermansia muciniphila*, a bacteria known for its health benefits (Roussel et al., 2022).

2. New Breakthroughs on Polyphenols

Selected research highlights

Polyphenols are abundant in Arctic berries frequently eaten by Nunavimmiut. Mounting evidence supports the beneficial potential of polyphenols against cardiovascular disease, particularly through their action on gut microbiota.

2.1 Specific classes of polyphenols, such as proanthocyanidins and ellagitannins, mitigate several aspects of metabolic syndrome, the collection of conditions that increase the risk of heart disease, stroke, and type 2 diabetes. There is growing evidence that gut microbiota is a key mediator of the health benefits of polyphenols (Anhê et al., 2019).

2.2 Polyphenolic extracts of cloudberry (*Rubus chamaemorus*), alpine bearberry (*Arctostaphylos alpina*) and lingonberry (*Vaccinium vitis-idaea*) all showed beneficial effects on insulin resistance, fasting and post-meal insulin levels in a murine model (Anhê et al., 2018). Consumption of specific Arctic berries could, therefore, reduce chronic inflammation related to obesity and metabolic disorders.

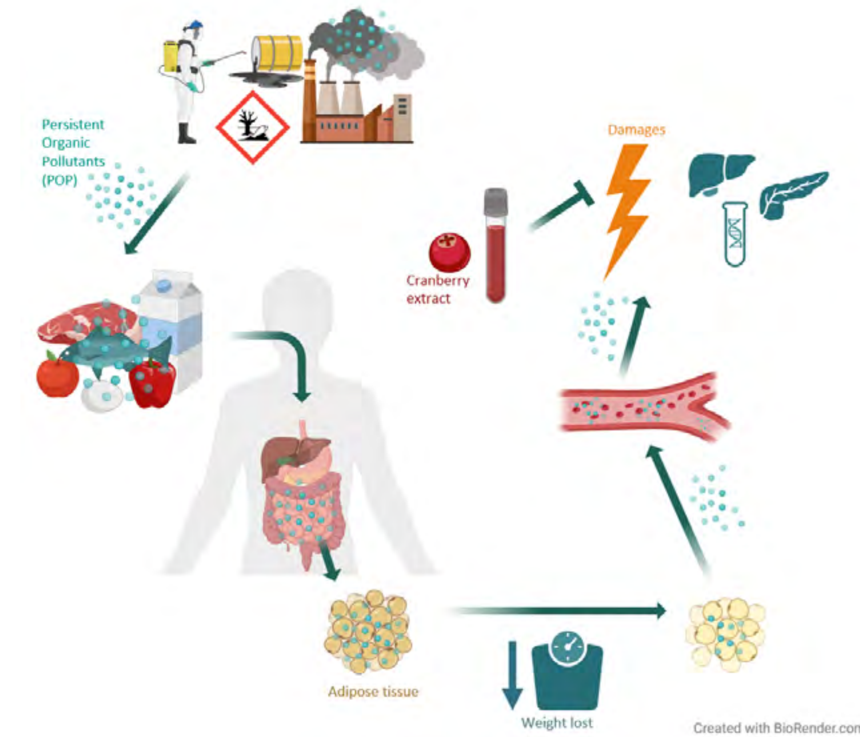
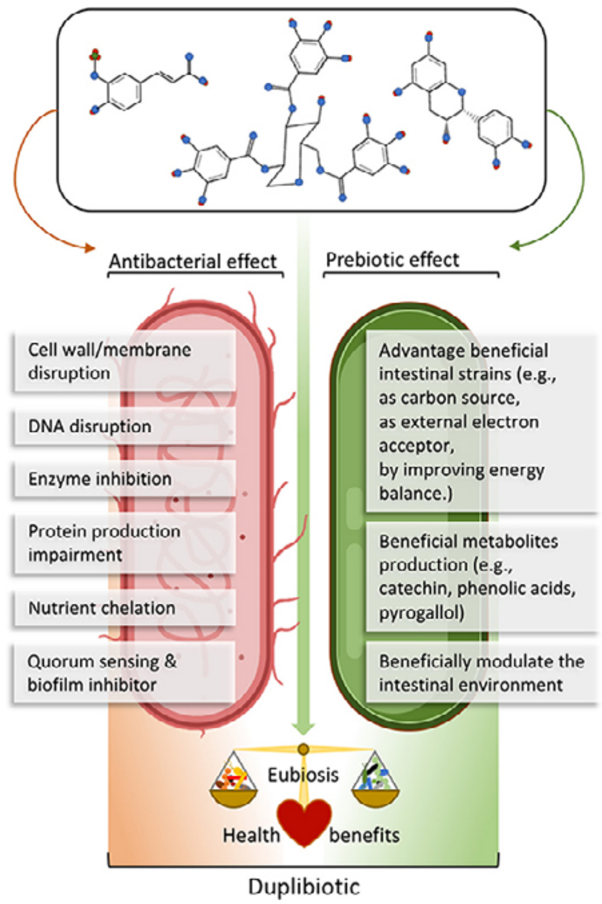


Figure 2.3
Representation of the impacts of persistent organic pollutants in the context of rapid weight loss. © Béatrice Choi

2.3 While weight loss induces the release of persistent organic pollutants (POPs) contained in adipose tissue and increases the pollutant levels in the body, the consumption of cranberry extracts used as a prebiotic decreased the load of these pollutants in mice models (Figure 2.3). These results are of interest to communities living in the Arctic who are particularly exposed to POPs through their diet (Choi et al., 2020a).

2.4 Polyphenols in blueberries reduced diet-related weight gain and improved insulin sensitivity. Specific classes of polyphenols in blueberries, including proanthocyanidins and anthocyanins, provided these beneficial effects on mice metabolic health, particularly through their action in modulating gut microbiota (Morissette et al., 2020).

Figure 2.5
Description of polyphenols direct antibacterial and prebiotic effects. Figure taken from Rodriguez-Daza et al., 2021, licensed under CC BY 4.0.



2.5 The term "duplibiotic" is proposed to describe polyphenols that modulate gut microbiota through their antibacterial and prebiotic action (Figure 2.5). The polyphenols' duplibiotic effect could help mitigate metabolic disturbances and intestinal dysbiosis. Therefore, polyphenols represent a target of interest in developing dietary strategies with therapeutic potential (Rodriguez-Daza et al., 2021).

Addressing Concerns about the Safe Consumption of Snow Geese

Snow geese are an important food resource for many Indigenous communities. The COVID-19 pandemic has raised concerns among some of these communities about the possibility of contracting the virus by eating these migratory birds. Because public health information at the time was not entirely conclusive, a research team obtained and analyzed samples from 500 geese and was able to conclude that these animals were not a vector for transmitting COVID-19. The results were quickly communicated, illustrating the ability of researchers to address the concerns of Indigenous communities (Frederick et al., 2021).

Infographics delivered to Indigenous communities and public health organizations in Canada. ©Alexandra Langwieder

3. Diet as a Determinant of Gut Microbiota

Selected research highlights

Diet is a major determinant of gut microbiota. Dietary changes can unbalance gut microbiota and result in cardiometabolic disorders. It is important to characterize gut microbiota, identify biomarkers and develop predictive tools for rapid and efficient diagnosis of cardiometabolic diseases.

3.1 In partnership with Nunavik collaborators, the taxonomic and functional characteristics of the gut microbiota of Nunavimmiut youths were identified from stool samples collected during the *Qanuilirpitaa?* 2017 survey. Results indicate that the Nunavimmiut gut microbiota exhibits high diversity and its composition is distinct from that of young adults from non-industrial and industrial societies (Figure 3.1). The Nunavimmiut diet, consisting of traditional and commercially produced foods, may explain their unique gut microbiota (Abed et al., 2022).

3.2 Progress has been made in the design of an optical sensor to detect key biomarkers produced by gut microbiota in real time. A model probe capable of real-time quantitative pH measurements *in vitro* has been designed. Preliminary experiments suggest that real-time pH measurements are also possible in the gut (Azzi, 2019).

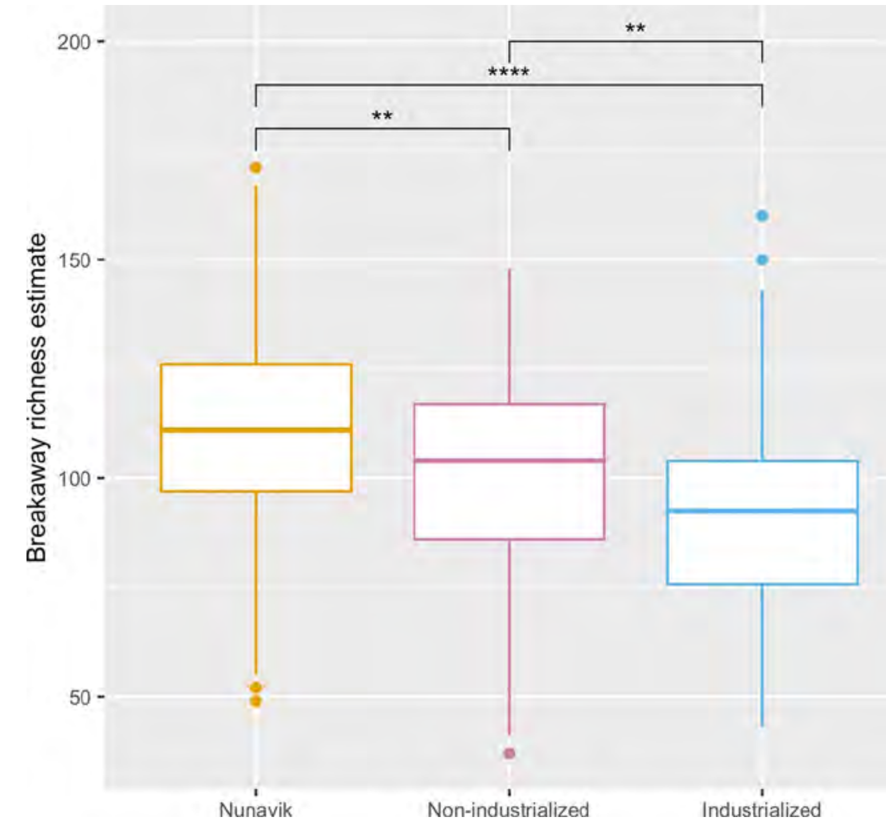
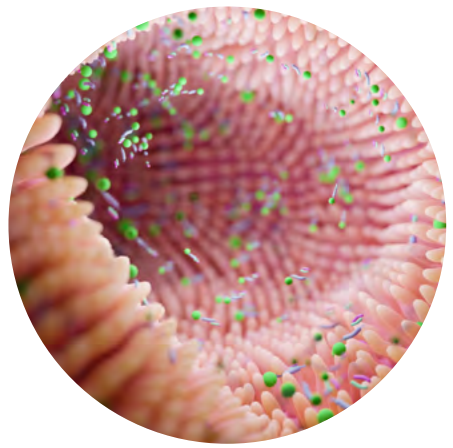


Figure 3.1
Intra-individual diversity of the gut microbiome in Nunavik Inuit is significantly higher than in non-industrial and industrial comparison groups using species-level relative abundance. The breakaway R package was used to estimate species richness. (*p-value ≤ 0.05, **p-value ≤ 0.01, ***p-value ≤ 0.001, ****p-value ≤ 0.0001). Figure taken from Abed et al., 2022, licensed under CC BY 4.0.

3.3 Bile acids have the potential to be used as biomarkers of gut microbiota. A convolutional neural network model was developed and successfully classified the five types of studied bile acids based on their spectra, even at low concentrations. The combined use of surface-enhanced Raman spectroscopy (SERS) and deep learning algorithms thus enabled the first detection and differentiation of bile acids (Lebrun et al., 2022).



4. The Gut-Brain Axis: Mechanisms of Action to be Further Investigated

Selected research highlights

An important bidirectional connection exists between the gut microbiota and the brain. However, the mechanisms involved in the regulation of brain functions by the gut microbiota are still poorly understood.

4.1 An obesogenic diet leads to neuroinflammation and an increase in blood-brain barrier permeability, which may impact the development of mood disorders. As a matter of fact, obesity is associated with an increased risk of developing a major depressive disorder. The gut microbiota is thus becoming a new therapeutic target to prevent and treat obesity-related comorbidities (Choi et al., 2020b).

"The gut-brain axis involves different pathways, including the microbiota and its metabolites. Several neurotransmitters and metabolites modulate immune system pathways that in turn influence behavior, memory, learning, locomotion, and mood and neurodegenerative disorders."

Adapted from Rutsch et al., 2020

4.2 The zebrafish (*Danio renio*) is becoming a promising animal model for better understanding the effects of gut microbiota on brain development. Several factors contribute to the relevance of this model, including its low cost, ability to evaluate large cohorts, the potential to obtain axenic larvae from non-axenic parents and availability of optical methodologies to probe larvae non-invasively by taking advantage of their transparency (Cornuault et al., 2022).

Selected research highlights

5. The Role of the Endocannabinoid System in Metabolic Health

The endocannabinoid system operates at the intersection between gut microbiota, gut-brain-axis communication and the host metabolism (Figure 5), playing a critical role in metabolic health and the development of obesity (Forte et al., 2020).

5.1 Poor dietary habits or obesity can disrupt the gut microbiome and the endocannabinoid system. Although the interactions between the gut microbiome and the endocannabinoid system remain to be defined, new nutritional or pharmacological approaches modulating these two systems could be beneficial for the treatment of metabolic syndrome or obesity (Iannotti and Di Marzo, 2021).

5.2 A study using axenic mice demonstrated the ability of gut microbiota to modulate the endocannabinoid system. Lacking a gut microbiome, these sterile mice showed profound alterations in the endocannabinoid system in the brain and gut, and particularly in the small intestine. These changes were reversed among adult male mice one week after a fecal microbiota transplant, which restored an active gut microbiome (Manca et al., 2020a; Manca et al., 2020b).

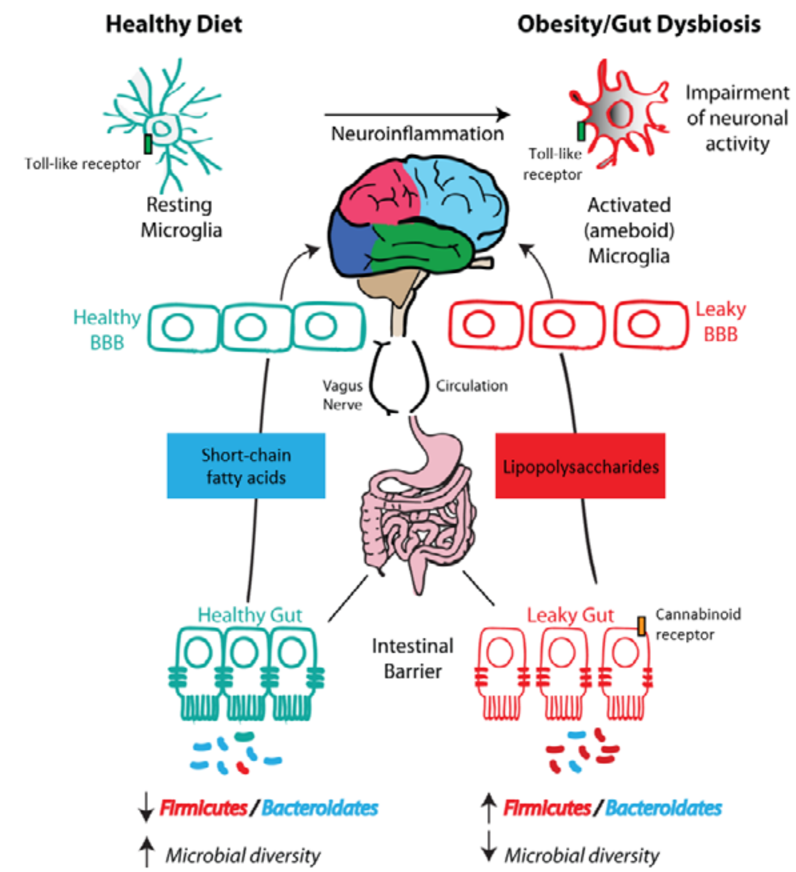


Figure 5
Interactions of healthy diet (green left side) and obesogenic diet (red right side) with gut microbiome–endocannabidoidome–brain axis. The diet influences gut microbiota composition and regulates intestinal permeability. Obesogenic diet leads to gut dysbiosis, inflammation, leaky intestinal and blood-brain-barrier (BBB). Figure taken from Forte et al., 2020, licensed under CC BY 4.0.

5.3 Gut microbiota and fatty acid intake determined endocannabinoid system (eCBome) signalling among a cohort of 195 individuals, independently of their body fat distribution. The study demonstrated that the intake of fatty acids was associated with levels of several eCBome mediators in plasma samples. Therefore, these results reveal the possibility of modulating plasma eCBome mediators with diet (Castonguay-Paradis et al., 2020).

5.4 A research team demonstrated that neurotransmitter signalling was altered among obese mice, resulting in dysfunction of adult hippocampal neurogenesis. These findings provide a molecular and functional mechanism to explain alterations in episodic memory in obese mice (Forte et al., 2021).

6. For New Food Systems

Selected research highlights

Traditional foods are integral to Inuit culture, nutrition, and health in the Arctic. However, food preferences have changed over the past few decades, with the majority of Nunavimmiut (68%) opting for a mixed diet comprising of both traditional foods and commercial products (Furgal et al., 2021).

6.1 From the Arctic to the South Pacific, the retail food sector in remote Indigenous communities shares common characteristics: high prices, low-quality foods, limited healthy food choices and increased availability of processed and unhealthy foods. This reality can result in a low nutritional value diet, exacerbating the already high levels of food insecurity in the Arctic and contributing to the development of chronic disease and obesity. Interventions are required to promote food sovereignty among Indigenous communities and develop healthy, affordable, and culturally appropriate food systems (Kenny et al., 2020).

6.2 Different dietary profiles strongly associated with socio-demographic characteristics were identified among Nunavik Inuit (Figure 6.2). The nutritional status, contaminant exposure and health issues of the different profiles will be studied to determine the possible solutions for adapted public health programs (Aker et al., 2022a).

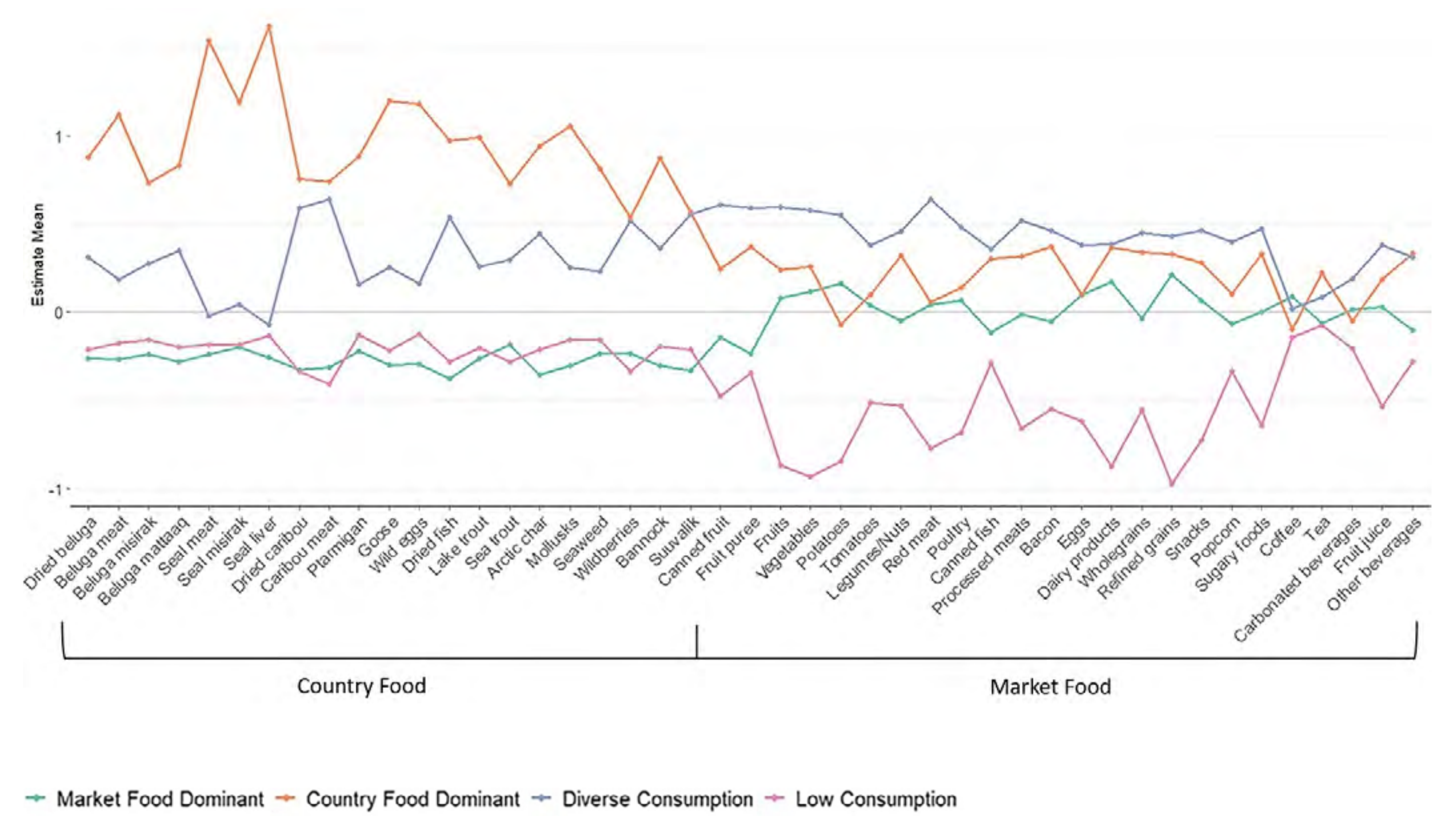


Figure 6.2
Four overall dietary profile have been identified: Market food-dominant profile included 42% of the study population. Women and Inuit adults aged 30–49 years were more likely to have this profile. Country food-dominant profile was the smallest group with 12,6% of the study population. Men, younger Inuit (aged 16–29 years), and older Inuit (≥ 50 years) were more often in this profile. Diverse consumption profile comprised 23,4% of the study population and included individuals who reported high consumption frequencies of both country and market food. Low consumption profile made up 21,9% of the study population and included individuals who reported high food insecurity. Figure adapted from Aker et al., 2022a, licensed under CC BY 4.0.

6.3 A research team is involved in a transdisciplinary participatory research initiative with the Nunavut community of Ikaluktutiak to implement a local food production system. To date, 16 outdoor mini-greenhouse prototype replicates have been installed to make outdoor agriculture possible in the High Arctic. Indoor hydroponic, aeroponic and soil-based systems have been implemented to support year-round farming. This research also enabled a recording of the knowledge associated with greenhouse practices and learning about the Ikaluktutiak inhabitants' perceptions of the nutritional quality of the fruits and vegetables available in grocery stores and their expectations concerning those grown locally (M. Dorais and C. Fournier-Côté, personal communication).

Pollutants in Commercial Foods

Canned foods, plastic-wrapped foods and many consumer goods may contain non-persistent chemicals. Exposure to these contaminants is receiving increasing attention in the Arctic, as an exploratory study conducted as part of the *Qanuilirpitaa?* 2017 survey suggests higher concentrations of some of these contaminants among the people in Nunavik compared with the general Canadian population. Women and Ungava Bay residents had the highest concentrations of these substances. Further studies are needed to confirm these findings, identify sources of exposure in the Arctic and investigate their effects on the health of Nunavik Inuit (Aker et al., 2022b).

7. Access to Quality Drinking Water

Selected research highlights

Many people living in the Arctic have limited access to drinking water. Remote Indigenous communities are particularly affected by this situation and face various challenges, including inadequate water quality and quantity, as well as intermittent supply service.

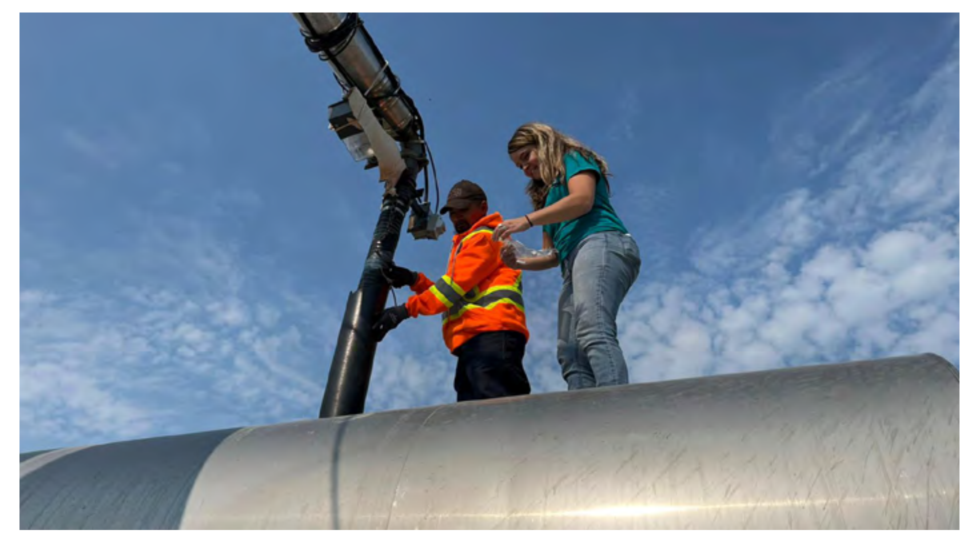
7.1 Culturally appropriate interventions that consider personal preferences on household risk perception and practices in accessing water are needed to improve and secure the drinking water supply for Arctic communities. Prevention of microbial and chemical contamination is the key to successful sanitation interventions from the water sources to the points of use (Cassivi et al., 2023).

7.2 A committee including researchers, Kativik Regional Government members, the Nunavik Regional Board of Health and Social Services and community representatives is working on drinking water issues. This collaboration enables the integration of local concerns and issues into research projects and ensures better knowledge transfer (S. Guilherme, personal communication).

7.3 A report on drinking water in Nunavik was produced in collaboration with the Makivik Corporation as part of the consultations for the creation of the Canada Water Agency. This report is based on a literature review and consultation with experts. The following issues were identified: (1) degradation of post-treatment water quality, (2) training of personnel for infrastructure use and maintenance, (3) protection of drinking water sources and (4) synergy between the different levels of government and water stakeholders (M. Rodriguez and D. Nadeau, personal communication).

7.4 To obtain a picture of the spatiotemporal variability of physicochemical and microbiological water quality, meteorological stations have been installed near drinking water sources and continuous monitoring of water quality from the source to the plant has been established in Kangiqsualujjuaq and Umiujaq, Nunavik. These efforts aim at determining protocols and decision-support tools for operators (M. Rodriguez, personal communication).

7.5 In Nunavik, a sampling program has shown that secondary disinfection by chlorination is not sufficient to ensure adequate protection during the domestic distribution and storage of drinking water. A decision support tool was developed in collaboration with the village of Kangiqsualujjuaq, Nunavik, to determine the appropriate amounts of chlorine to achieve disinfectant residuals that meet international standards while limiting the generation of potentially harmful disinfection by-products and chlorine tastes and odours that inhibit Nunavimmiut's consumption of tap water (Garcia-Sanchez, 2022).



Research Projects Cited in this Chapter

The knowledge and technological advances referenced in this chapter were generated by several Sentinel North interdisciplinary research teams. These scientific contributions were gathered from the projects listed below, which involved, in addition to the principal investigators, numerous researchers, graduate students, postdoctoral fellows, research professionals, collaborators, partners from northern organizations and national and international partners from the public and private sectors.

- Characterization and modelling of the key interrelationships of northern water systems under climatic, geosystemic, and societal pressures

  Principal Investigator: René Therrien (Dept. of Geology and Geological Engineering)

- Deciphering host-microbial interactions for cardiometabolic and mental health disorders with novel multimodal light-based sensing tools

  Principal Investigators: Denis Boudreau (Dept. of Chemistry), André Marette (Dept. of Medicine)

- NUNARISK: Early warning system for drinking water management and monitoring through the analysis of online and continuous environmental data

  Principal Investigators: Manuel J. Rodriguez (Graduate School of Land Management and Regional Planning), Daniel Nadeau (Dept. of Civil and Water Engineering)

- Optogenetics investigation of microbiota influence on brain development and epigenetics

  Principal Investigators: Paul De Koninck (Dept. of Biochemistry, Microbiology and Bio-informatics), Sylvain Moineau (Dept. of Biochemistry, Microbiology and Bio-informatics)

- Participatory action for an Inuit-led research on food production and nutrition in Inuit Nunangat

  Principal Investigators: Martine Dorais (Dept. of Phytology), Caroline Hervé (Dept. of Anthropology)

- The gut microbiome: Sentinel of the northern environment and Inuit mental health

  Principal Investigators: Richard Bélanger (Dept. of Pediatrics), Gina Muckle (School of Psychology)

- Sentinel North partnership research chair on ecosystemic approaches to health

  Chairholder: Mélanie Lemire (Dept. of Social and Preventive Medicine)

- Sentinel North research chair on the impact of animal migrations on Arctic ecosystems

  Chairholder: Pierre Legagneux (Dept. of Biology)

Research Projects Cited
in this Chapter

Some results presented in this chapter are also drawn from research projects conducted by recipients of Sentinel North Excellence scholarship and postdoctoral fellowship awards.

- Sensor-in-fibre optical probes for molecules sensing in the gastro-intestinal tract of muridae models relevant to cardiometabolic diseases
  Victor Azzi (Master's Scholarship)
- Évaluation de la qualité de l'eau potable de la source au robinet au Nunavik
  Cristian Ruben Garcia Sanchez (Master's Scholarship)
- Impact de la modulation du microbiote sur l'excrétion de polluants organiques persistants lors d'une perte de poids
  Béatrice Choi (Ph.D. Scholarship)
- Synthèse de nanosondes luminescentes dans l'étude *in vivo* de marqueurs du microbiote intestinal
  Nicolas Fontaine (Ph.D. Scholarship)
- The association between per and polyfluoroalkyl substances (PFAS) and metabolic outcomes among Nunavimmiut adults
  Amira Aker (Postdoctoral Fellowship)
- Déterminants de la santé cardiométabolique et des habitudes alimentaires des Inuit du Nunavik en 2017
  Janie Allaire (Postdoctoral Fellowship)
- Approvisionnement en eau potable dans les communautés autochtones en région arctique : suivi et évaluation des risques sanitaires
  Alexandra Cassivi (Postdoctoral Fellowship)
- Utilisation des phages virulents pour contrôler le microbiote du poisson-zèbre
  Jeffrey Cornuault (Postdoctoral Fellowship)

Sentinel North has developed partnerships with leading international institutions to conduct innovative and interdisciplinary research projects. The following joint collaborative project has contributed to the results of this chapter.

- Joint International Research Unit for chemical and biomolecular research of the microbiome and its impacts on metabolic health and nutrition
  Director: Vincenzo Di Marzo (Dept. of Medicine)
  National Research Council, Italy
  Associated with the CERC in the microbiome-endocannabinoidome axis in metabolic health

Consiglio Nazionale delle Ricerche

Ongoing Sentinel North Research Projects

Several research projects supported by Sentinel North and through joint funding initiatives are ongoing as part of the second phase of the program (2021-2025). These projects, listed hereunder, continue to fill fundamental gaps in our scientific knowledge of the changing North.

- Development of resilient municipal wastewater treatment infrastructure targeting water reuse in Nunavik, Québec

  Principal Investigator: Céline Vaneeckhaute (Dept. of Chemical Engineering)

- Interactions between the northern environment and chronobiotics: Impact on cardiometabolic and neurometabolic health

  Principal Investigators: Alexandre Caron (Fac. of Pharmacy), Andréanne Michaud (School of Nutrition)

- Linking the marine environment and the nutritional quality of shellfish and beluga near Quaqtaq

  Principal Investigators: Mélanie Lemire (Dept. of Social and Preventive Medicine), Jean-Éric Tremblay (Dept. of Biology)
  Project jointly funded by Sentinel North and Institut nordique du Québec

- NUNARISK: Early warning system for drinking water management and monitoring through the analysis of online and continuous environmental data

  Principal Investigators: Manuel J. Rodriguez (Graduate School of Land Management and Regional Planning), Daniel Nadeau (Dept. of Civil and Water Engineering)

- Participatory action for an Inuit-led research on food production and nutrition in Inuit Nunangat

  Principal Investigators: Martine Dorais (Dept. of Phytology), Caroline Hervé (Dept. of Anthropology)

- Sustainable and resilient country food systems for future generations of Nunavimmiut – Promoting food security while adapting to changing northern environments

  Principal Investigators: Frédéric Maps (Dept. of Biology), Tiff-Annie Kenny (Dept. of Social and Preventive Medicine)

- The exposome-microbiota-brain axis under the microscope to tackle environment-health interactions in the North

  Principal Investigators: Paul De Koninck (Dept. of Biochemistry, Microbiology and Bio-informatics), Pierre Ayotte (Dept. of Social and Preventive Medicine)

- TININNIMIUTAIT: Assessing the potential of local marine foods accessible from the shore to increase food security and sovereignty in Nunavik

  Principal Investigators: Lucie Beaulieu (Dept. of Food Sciences), Ladd Johnson (Dept. of Biology)

- Extreme zooming on intestinal permeability and the western-style diet: Unravelling the role of dietary antigens on the prevalence of cardiometabolic and mental health diseases in the North

  Principal Investigators: Flavie Lavoie-Cardinal (Dept. of Psychiatry and Neurosciences), Denis Boudreau (Dept. of Chemistry)

- Sentinel North partnership research chair on ecosystemic approaches to health

  Chairholder: Mélanie Lemire (Dept. of Social and Preventive Medicine)

- Sentinel North partnership research chair on the gut microbiome-endocannabinoid system as an integrator of extreme environmental influences on bioenergetics

  Chairholder: Cristoforo Silvestri (Dept. of Medicine)

- Joint International Research Unit for chemical and biomolecular research of the microbiome and its impacts on metabolic health and nutrition

  Director: Vincenzo Di Marzo (Dept. of Medicine)

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