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From the Panel on Nutrition, Dietetic Products, Novel Food, and Allergy of the Norwegian Scientific Committee for Food and Environment

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Preparation of the protocol

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the protocol. The project group consisted of VKM members, external experts, and VKM staff.

Authors of the protocol

The authors have contributed to the opinion in a way that fulfils the authorship principles of VKM (VKM, 2023). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group and/or the VKM Panel on Nutrition, Dietetic Products, Novel Food, and Allergy.

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Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third-party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Abbreviations

LMM – linear mixed model

NFC – NutriFoodCalc

p-AR – provisional average requirement

UIC – urinary iodine concentrations

UIE – urinary iodine exposure

UL – tolerable upper intake levels

Glossary

Provisional average requirement: A temporary estimate of the average daily intake level of a nutrient that is assumed to meet the requirement of half of the healthy individuals in a given population group, used when the available evidence is insufficient to derive a full Average Requirement (AR). The provisional AR, which is an approximation of AR, has larger uncertainty than AR. It is calculated by multiplying adequate Intake (AI) by a factor of 0.8. It can be used when an AR cannot be determined (Blomhoff et a., 2023).

Tolerable upper intake level: the maximum level of total chronic daily intake of a nutrient (from all dietary sources) which is not expected to pose a risk of adverse health effects to humans (EFSA, 2024).

Background exposure/ intake' refers to the level of exposure/ intake that occurs from existing dietary sources without iodized household salt and iodized salt in bread that are changing in the current intakes and the scenario adjustments.

Background as provided by the Norwegian Food Safety Authority

The Iodine Fortification Programme was launched in June 2025 by the Norwegian Food Safety Authority (NFSA), the Directorate of Health, and the Norwegian Institute of Public Health to help improve and ensure adequate iodine intake in the population. The programme is based on scientific assessments from the National Nutrition Council (2016 and 2021). Within the programme, the Directorate of Health encourages food manufacturers to add 20 µg iodine per 100 g to household salt, salt used in industrially produced bread and other bakery products, and plant-based milk alternatives.

The benefit and risk assessment of iodine in salt and bread conducted by VKM et al., (2020) showed how iodine fortification in household salt and bread and bakery products can increase iodine intake among groups with insufficient intake, such as women of childbearing age. At the same time, VKM identified that some young children may have an excessive iodine intake with increased fortification.

The Iodine Fortification Programme consists of three components:

- Regulation: The NFSA administers the regulations on the addition of vitamins, minerals, and other substances to foods. The addition of iodine according to the Directorate of Health's recommendation is voluntary under current legislation.
- Monitoring: The Norwegian Institute of Public Health monitors iodine status in the population and assesses health effects. The NFSA monitors the availability of iodine-fortified products on the Norwegian market and the iodine content in relevant foods and food supplements.
- Communication: The Directorate of Health is responsible for communication, including information and dialogue with the food industry, health professionals, and the public.

The range between insufficient and excessive iodine intake is narrow, making it important to monitor whether the fortification measure has the intended effect. For the NFSA, it is particularly important to monitor developments and the effects of the measure to minimize the risk of excessive iodine intake in certain groups. Therefore, the NFSA requires calculations of iodine intake based on the latest dietary surveys and new data on iodine content in key food groups as part of risk management.

Terms of reference as provided by the Norwegian Food Safety Authority

Part 1 of the assignment

Estimate and assess current iodine intake and various scenarios

a) The NFSA requests VKM to **estimate** and assess iodine intake in different population groups under the following conditions:

- Current iodine intake (before programme launch)
- Fortification scenario with 20 µg iodine per 100 g in:
  - Household salt
  - Salt used in industrially produced bread and other bakery products

Estimates should be calculated using different coverage levels of iodised salt (e.g., 25%, 50%, 75%, 100%) in both household salt and industrial bread and other bakery products. All estimates and scenarios should be presented with, for example, 5th, 50th, and 95th percentiles.

Mattilsynet requests an assessment of the contribution of iodised salt (household and industrial bread and other bakery products) to total iodine intake in different population groups.

b) The NFSA requests VKM to estimate and assess the proportions of different population groups that are below and above the reference values for iodine intake, and describe how these proportions change with varying coverage levels of iodised salt use (household salt and salt in industrial bread and other bakery products):

- Estimate proportions in the different population groups with:

  o Intake below the provisional average requirement (p-AR)

  o Intake above the tolerable upper intake level (UL)

- Assess how iodine fortification affects:
  - Total iodine intake, including variation in intake
  - Risk of insufficient intake (below p-AR)
  - Risk of excessive intake (above UL)

Describe sources of iodine

The NFSA requests VKM to describe how the dietary sources of iodine change in the different population groups at varying coverage levels of iodised salt use in industrial bread and other bakery products.

• Naturally occurring sources (e.g. milk, fish, eggs)

• Food supplements

• Fortified salt (household or industrial) and plant-based milk alternatives

Assess the effect of the Iodine Fortification Programme

The NFSA requests VKM to assess the programme's effect on iodine intake in various population groups, and the uncertainty related to the calculations.

- Assess population groups that will benefit from the measure or are at risk of excessive intake.
- Assess uncertainties related to estimates and modelling.

Part 2 of the assignment

The request from the NFSA also includes a Part 2. The scope of the assignment in Part 2 will be discussed later, once we have reviewed the results from Part 1.

1 Introduction

The purpose of this protocol is to describe how VKM will perform the risk assessment of increased iodine fortification of household salt and salt used for industrial bread production for the general Norwegian population aged 1 to 80 years. Iodine intake is based on the national dietary surveys and salt fortification coverage scenarios. The final report will be a Tier 2 risk assessment, evaluating iodine intake in relation to established reference values (DRVs) for iodine. This protocol is limited to Part 1 of the assignment from the Norwegian Food Safety Authority (NFSA). Part 2 of the assignment from the NFSA will be addressed at a later stage.

In 2020, VKM published a benefit and risk assessment of increasing the iodine content of household salt and the salt used in bread and bakery products (VKM et al., 2020). The main differences between the intake calculations performed in 2020 and those required for the current assignment are as follows: In 2020, VKM constructed scenarios based on different iodine concentrations in household salt and bread salt, namely 15, 20, 25 and 50 µg per gram of salt. In the forthcoming assessment, VKM will estimate iodine intake assuming a fixed iodine concentration of 20 µg per gram of salt in household salt and salt used in bread and other bakery products, while varying the proportion of these salts that are iodised. This means that different levels of fortification coverage, for example 25, 50, 75 or 100% of all household salt and bread salt being iodised with 20 µg iodine, will form the basis of the intake scenarios, which VKM refers to in the protocol as iodised salt fortification coverage scenarios.

In addition, new dietary survey data for adults, new analytical values for iodine in a range of foods, and a revised reference value for provisional average iodine requirement are now available. The 2020 report also included a comprehensive systematic review of iodine and a wide range of health outcomes, as well as a re-evaluation of the UL from SCF (2002).

We plan to send the risk assessment to three referees.

1.1 Recommendations for the Iodine Fortification Programme from the Directorate of Health

The objective of the Iodine Fortification Programme is to improve the iodine status of the population. Priority groups include adolescent girls, young women/women of reproductive age, pregnant and lactating women, young children, as well as individuals with a low intake of cow's milk and fish, such as certain immigrant groups and those adhering to vegetarian or vegan diets (Abel, Hay, et al., 2025).

The recommendations for iodine additions in the Iodine Fortification Programme from the Directorate of Health are as follows: household salt and salt used in bread and other bakery products may be fortified with 20 µg of iodine per gram of salt, and plant-based milk alternatives may be fortified with up to 22.5 µg of iodine per 100 ml.

Fortification is currently voluntary (FOR-2010-02-26-247), but the authorities are planning to introduce mandatory fortification.

1.2 General regulations of fortification and permissions

A wide range of vitamins, minerals, and certain other substances may be added to food products, provided that the fortification level complies with established maximum limits in Appendix 1 in Forskrift om tilsetning av vitaminer, mineraler og visse andre stoffer til næringsmidler (FOR-2010-02-26-247). It is also possible to obtain authorisation to add amounts exceeding the standard regulatory limits if the NFSA assesses that the addition of the substance to the specific food category does not pose a risk to human health. General regulations on fortification are also applicable for iodine fortification.

The NFSA has granted several authorisations for the addition of iodine across a range of food categories. Products for which fortification has already been authorised are listed in the positive list, Annex 1 in the Regulation on the Addition of Vitamins and Minerals to Food (FOR-2010-02-26-247). The positive list includes permitted amounts for each food category. As of 18 February 2026, authorisations for iodine fortification have been granted for a number of food categories, including: plant-based milk alternatives, plant-based cheese alternatives, electrolyte beverages, meal replacements, special milk drinks for young children aged 1–3 years, energy bars, plant-based alternatives to milk-based desserts, household salt, salt used as an ingredient in bread and bakery products, and salt used as an ingredient in bouillons, soups, sauces and other ready-made foods.

The permitted amount of iodine in household salt was increased from 5 to 20 µg iodine per gram of salt in March 2023. In salt used as ingredient in bread and bullions, sauces, soups and ready-made foods it has been permitted to add 20 µg iodine per gram of salt since before the supplementary national provisions in Forskrift om tilsetning av vitaminer, mineraler og visse andre stoffer til næringsmidler entered into force on the 1st of January 2020.

1.3 Population groups to be included in the assessment

In line with the assignment, VKM's iodine estimates and assessments will include all population groups from age 1 year covered by the national dietary surveys, see Table 1.3-1. The adult population (age 18 and older) will be divided in three age groups. Results in all age groups except in 1-year-olds will be presented by sex. The 1-year-olds will not be separated by sex but by breastfeeding status as reported in Spedkost 3 (those who are breastfed and those who are not).

Table 1.3-1: Population groups to be included in VKM's assessment.

Population groups	
Males	**Females**
1-year-olds*	1-year-olds*
2-year-olds	2-year-olds
4-year-olds	4-year-olds
9-year-olds	9-year-olds
13-year-olds	13-year-olds
18-29 years	18-29 years
30-49 years	30-49 years
50-80 years	50-80 years

*1-year-olds will not be separated by sex but will be divided into two groups: breastfed and non-breastfed.

1.3.1 Groups at risk of low, and high iodine intakes

In line with established risk assessment methodology, VKM will also, as far as reliable data permit, seek to identify and describe subgroups that may be at risk of either low or high iodine intakes.

Pregnant and breastfeeding women are highlighted as key groups underpinning the rationale for the iodine fortification programme (Abel, Hay, et al., 2025). Other sub-groups that may be at possible risk of too low iodine intakes are people omitting milk/ dairy, eggs, or fish from the diet (e.g. vegans/ vegetarians or, people with allergies, and certain immigrant groups) (Abel, Hay, et al., 2025). Seaweed consumers or people/ groups with a high intake of milk, fish or supplements may be considered at possible risk of excessive iodine intakes (Abel et al., 2023; VKM et al., 2020).

We anticipate that these sub-groups will be too small for separate intake modelling or assessments against the DRVs. Instead, we will count the number of individuals in each sub-group and evaluate whether their mean or median iodine intake is above or below that of the total population. The Norkost 4 questionnaire does not differentiate between pregnancy and lactation, and it will therefore not be possible to separate pregnant women from breastfeeding women in the intake calculations.

2 Data input

To evaluate risk of insufficient or excessive iodine intakes in various population groups before and after introduction of the Iodine Fortification Programme, we will compare the estimated usual iodine intakes at baseline, and iodine intakes in different iodine fortification coverage scenarios with established dietary reference values. All the data required to carry out this risk assessment are described in the sections below.

Iodine intake at baseline is assumed to remain constant across the various coverage scenarios, whereas/except for the intakes of iodine from household salt and bread with iodised salt which will vary in the scenarios.

Sections 2.1–2.5 present the most detailed information for each of the individual elements required as data inputs for calculating baseline iodine intakes and the scenario estimates. In section 2.6 all factors to consider are summarised in an overview table. The premises that will be applied specifically for the estimation of baseline iodine intakes are described in section 2.6.1, while those that will be applied in the scenario calculations are presented in section 2.6.2. Section 2.7 provides the established dietary reference values for iodine that will form the basis of the risk assessment.

2.1 Data sources and data level

Intake data will be based on the national dietary surveys. Proportions of iodised salt will be based on data from additional questions in Norkost 4 or from Statistics Norway.

2.1.1 National dietary surveys

VKM will use intake data from the national dietary surveys: adults (Norkost 4, ages 18–80 years) (Myhre et al., 2024), children and adolescents (Ungkost 3, ages 4, 9, and 13 years) (Hansen et al., 2015; Hansen et al., 2016), 2-year-olds (Småbarnskost 3) (Astrup et al., 2020), and 1-year-olds (Spedkost 3) (Paulsen et al., 2020).

The main characteristics for the surveys are presented in table 2.1.1-1.

Table 2.1.1-1 The Norwegian dietary surveys planned to be used in the risk assessment.

Survey	Year	Age (years)	N	Methods	Estimation of food portions
Norkost 4 Myhre et al., 2024	2022-2023	18 - 80	1964	Two 24-hour recalls, by telephone	Natural units (e.g. apples, eggs), household measures, or food portion size images
Ungkost 3 Hansen et al., 2015	2015	4 9 13	399 636 687	Four-days web-based food diary	Natural units (e.g. apples, eggs), household measures, or food portionsize images
Småbarnskost 3 Astrup et al., 2020	2019	2	1413	Semi-quantitative food frequency questionnaires[1]	Predefined household units (eggs, slice of bread, decilitres etc.), or food portion size images

Survey	Year	Age (years)	N	Methods	Estimation of food portions
Spedkost 3 Myhre et al., 2020	2019	1	1957	Semi-quantitative food frequency questionnaires[1]	Predefined household units (eggs, slice of bread, decilitres etc.), or food portion size images

[1]The caretaker was instructed to consider the previous two weeks as a timeframe when completing the questionnaire.

In the survey data that will be made available to VKM, the sample size (N) includes all participants with two 24-hour recalls (Norkost 4), or at least three food diary registration days (Ungkost 3). For FFQ data (Småbarnskost 3, Spedkost 3) a few respondents with extremely low or high energy intakes and questionnaires returned after deadline, have been excluded in the main reports (Astrup et al. 2020 and Paulsen et al., 2020).

All individual food items reported to be consumed in the national dietary surveys are included in the NutriFoodCalc system (NFC; the University of Oslo). NFC is a food composition and nutrient calculation system combining dietary assessment data with food composition data. Each dietary survey has a designated database where all foods reported are matched with updated nutrients at the time of the data collection, including energy intake and bread consumption which will be used in the assessment. Sped- and Småbarnskost 3 is calculated in AE18, Ungkost 3 is calculated in AE14, and Norkost 4 is calculated in N4. It is only the N4 database that has iodine values. Therefore, an updated N4 will be used as bases for the iodine calculations for all three surveys.

2.1.2 Breastmilk volumes and iodine concentrations

To estimate iodine intake from breastmilk in 1-year-olds, the volume consumed will be derived from recently published global age-specific breastmilk intake estimates by Rios-Leyvraz & Yao (2023) and breastmilk iodine concentration from a recent Norwegian study performed in a representative sample from 30 randomly selected municipalities in Innlandet county (Aarsland et al., 2023).

In 2-year-old children, iodine intake from breastmilk will not be included, since only 8% (Astrup et al., 2020) were breastfed at 2 years of age, and the intake is likely low.

2.1.3 Population registry data to correct for response bias

The national dietary surveys have varying participation rates and survey respondents may be overrepresented or underrepresented compared with the national population. Therefore, VKM will use official population registry data from Statistics Norway (SSB) to adjust modelled results for potential response bias. Depending on the survey, the adjustment will include all or some of the factors: age, sex, self-reported education level (of respondent, or parent), and geographic region (as defined at the time of the survey sampling).

2.1.4 Data on trade, market shares and other data for salt

For this risk assessment we will need proportion data for iodised vs non-iodised salt for estimatingiodine intakes at baseline.

Proportion data for iodised salt will be collected from the additional questionnaire regarding salt use in Norkost 4 or dietary statistics from Statistics Norway. As we are drafting the protocol, we do not have access to Norkost 4 data. We will therefore assess which dataset is likely to provide the most accurate estimates when the data become available.

2.1.5 Biomarker data for sensitivity analyses of total salt intake

Sensitivity analyses of total salt intake in adults will be estimated based on external biomarker data from the Tromsø 7 Study. Sodium in 24-hour urine was collected in 496 participants aged 40-69 years from the Tromsø region. Data was collected in 2015-2016.

Sensitivity analyses of total salt intake in 2-year-olds will be based on measured sodium from two repeated spot urine samples collected from 76 of 327 2-year-olds participating in the National Monitoring Program. The data were collected in 2022-2023 (currently unpublished).

For other age groups in the national dietary surveys (age 4-, 9-, and 13-year-olds) VKM has not identified any sodium excretion data.

2.2 Food composition data for iodine

All reported food intake from the national surveys are available in NutriFoodCalc (NFC). Sources to iodine may be foods naturally containing iodine or iodine fortified sources or food supplements. Food supplements are described in section 2.5.

For iodine content in foods, VKM will compile a designated iodine database based on N4, with up-to-date iodine content data provided by the NFSA (received 30th January 2026 from the NFSA). The VKM iodine database will be used for all dietary surveys.

VKM has received new values for iodine contents in the following foods and food groups:

- Shellfish and molluscs
- Selected fish species (tusk, cod, saithe, pollack, greater argentina and haddock)
- Farris (Norwegian natural spring water)
- Eggs
- Plant-based alternatives to milk
- Seaweed and kelp
- Vegetables (onion, carrot, cauliflower, broccoli, tomato, swede, spinach, leek, iceberg lettuce, celeriac root, cucumber, red cabbage)
- Ice cream (tub ice cream)
- Plant-based sandwich spreads

These values will be compared with existing data in NFC/the food database N4. We will replace N4 iodine values with new values, but also consider the number of analyses, year of analyses, and differences in fodder. Differences between old and new values will be described. For all other values we will use the iodine values in N4.

In the baseline intake, 5 µg iodine per gram will be used instead of 20 µg iodine per gram for household salt, which is now permitted. The regulations allow iodine to be added to the foods recommended by the Norwegian Directorate of Health as part of the iodine fortification program, including household salt. Although the regulatory change entered into force in 2023, the regulatory changes are a necessary foundation for the iodine fortification program. To address the mandate concerning the effect of the iodine fortification program, the iodine content is therefore set to 5 µg iodine per gram salt. The food industry was not encouraged to modify its products until the launch of the iodine fortification program in June 2025. VKM has contacted a major supplier of household salt (Jozo), which informed that their salt was not fortified with 20 µg until September 2025, after the Iodine fortification programme was launched. As described in section 1.2, in addition to household salt and salt in bread, which are addressed in sections 2.3 and 2.4, general permission for iodine fortification is granted for plant-based alternatives to milk and for salt used in bouillons, sauces, soups, and readymade products.

The Iodine Fortification Programme currently recommends iodine fortification of plant-based alternatives to milk. However, the national dietary surveys in children and adolescents (Småbarnskost 3 and Ungkost 3) have not registered use of plant-based milk, and intake in adults is low (Norkost 4). According to the Norkost 4 report (Table 25 in report) the mean (SD) intake in grams per day, was 6 (43) in men and 15 (69) in women, and the contribution to the iodine intake (Table 65 in report) was 0%. Due to low intakes, these products will not be part of the iodine fortification scenarios in this assessment. We will, however, include any newly fortified products in the iodine database described above. The products will thus be included in the background diet if the products are recorded in the dietary surveys, but their contribution to iodine will be low.

Sauces, soups, buillons, and ready-made foods may contain high amounts of salt, and some are coded in the N4 food database with high iodine contents, while others are without iodine. For these products we will use iodine values already included in the N4 food database.

For pregnant and breastfeeding women, VKM explore if data from the Norwegian Public Health Survey can be used for identifying key iodine sources, e.g. milk, fish, and food supplements.

2.3 Estimation of intake of household salt

Intake of household salt will be estimated as proportions of total salt intake. Household salt refers to all salt used and added within the household, including table salt (salt added to food at the table) and salt used in home preparation and cooking, such as in homemade bread and other bakery products, and other foods prepared in the home. Data from dietary surveys are generally anticipated to underestimate true salt intake because the dietary survey methods based on self-reports either fail to account for, or capture only poorly, especially salt added at the table. Norwegian dietary surveys include standard salt content for homecooked foods (e.g., pasta boiled in salted water), but table salt is not recorded.

2.3.1 Estimation of total salt intake in adults, adolescents and children

VKM has considered two data sources for estimating total salt intake: national dietary surveys, and external biomarker data. VKM chose to use 24-hour urinary excretion data from the Tromsø 7 study (collected 2015-2016) in adults in its iodine report from 2020. VKM has re-evaluated the advantages and disadvantages of both data sources and concluded that in the current assessment, dietary surveys will be used in the main analysis, and biomarker data in sensitivity analyses (section 3.2.4).

The following arguments have been evaluated for the use of Norkost 4 (dietary survey) vs the Tromsø 7 study (urinary excretion):

- Although Norkost 4 is likely to underestimate table salt intake, the underestimation is expected to be small: the difference in the mean salt intake between the two surveys Norkost 4 and Tromsø 7 (for the same age group 40-69 years) is approximately 1 gram and 2 grams of salt per day for women and men, respectively, and only a small proportion of this will be iodised household salt.

- Norkost 4, and the dietary surveys in general, provide individual-level data, which enables modelling of covariations (e.g. iodine from salt in bread, and iodine from other dietary intake). When using external biomarker data, this individual-level covariance will be ignored, which could also lead to underestimation.

- Norkost 4 contains more recent data than Tromsø 7 and is nationally representative, whereas Tromsø 7 is a regional study.

While we do not expect the choice of method to substantially influence the estimated iodine intake, sensitivity analyses for adults will be conducted using data from Tromsø 7 to verify this assumption.

For the age groups 4, 9, and 13 years, total salt intake will be estimated using dietary survey data from Ungkost 3. Since no external biomarker data is available, total salt will be estimated by downscaling adult sodium intakes from the Tromsø 7 Study in sensitivity analyses, as done in VKM's previous iodine report from 2020. As sodium intake is strongly correlated with total energy intake (Whelton et al., 2012), we assume a linear relationship between sodium and energy intake across age groups. Mean energy intakes from adults (Norkost 4) and from children (Ungkost 3) will be used to derive age-specific scaling factors, calculated separately for boys and girls.

For 2-year-olds, total salt intake will be estimated using Småbarnskost 3, with external biomarker data from the National Monitoring Programme used for sensitivity analyses.

VKM will assume that 1-year-olds have a very limited intake of household salt and estimates of household salt intake will therefore not be calculated for this age group.

Table 2.3.1-1 shows the different datasets that will be used to estimate total salt intake in adults and children.

Table 2.3.1-1 The datasets that VKM will draw upon to estimate total salt intake across the different population groups, and which will serve as the foundation for estimating household salt intake.

Population group	Main analyses	Sensitivity analyses
Adults, men	Norkost 4	Tromsø 7
Adults, women	Norkost 4	Tromsø 7
4-, 9- and 13-year-olds	Ungkost 3	Tromsø 7, extrapolated from adults
2-year-olds	Småbarnskost 3	National Monitoring Program

2.3.2 Household salt as a proportion of total salt intake

In the previous iodine assessment from 2020, VKM identified studies from England (Sanchez-Castillo et al., 1987), the USA (Mattes & Donnelly, 1991), and Denmark (L. Andersen et al., 2009), which showed that the intake of household salt among adults is approximately 10% of the total salt intake. Mattes and Donnelly (1991) estimated that approximately 55% of the household salt is added at the table and 45% during cooking.

We will investigate whether any newly published studies in adults are available that are relevant in the sense that they reflect eating patterns comparable to those in Norway. In this context, relevance refers specifically to the balance between industrially added salt and household salt. To address these questions, we will conduct a forward citation search based on the papers above.We will also examine whether studies exist on the use of household salt among younger age groups.

2.3.2.1 Proportion of iodised household salt relative to total household salt

Available data on use of type of household salt from the Questionnaire in Norkost 4 will preferably be used to identify a rough estimate of proportions of use of iodised salt for estimates of intakes at baseline in adults and children. Alternatively, we will use data on proportions iodised vs non-iodised from Statistics Norway.

In the iodine fortification coverage scenarios (see section 2.6.2) the proportions of iodised vs non-iodised will be determined by the coverage levels.

2.4 Bread and other bakery products

Iodine intake from salt in bread and other bakery products depends on three variables: the iodine level in the salt, the salt content in the products, and the amount of bread and other bakery products consumed.

Salt content in bread and other bakery products will be based on analytical data provided by the NFSA (see table 2.4.2-1). Consumption volumes for bread and other bakery products will be estimated from the national dietary surveys.

As general permission is granted for the use of iodised salt in bread prior to the launching of the Iodine Fortification Programme, bread and other bakery products on the Norwegian market may be produced with iodised or non-iodised salt, and iodine levels may vary. Bread and other bakery products may be industrially produced in Norway, imported from other countries, or homemade. These are all factors that will influence the contribution to iodine in estimates for iodine intakes at baseline, and in the various iodine fortification coverage scenarios, see sections 2.4.2-2.4.5.

2.4.1 Definition of bread and other bakery products

VKM will define 'bread' as all whole grain and fine bread, rolls, baguettes, ciabatta, focaccia, bagels, crispbreads, and dry bread such as rusks usually eaten with bread spreads, and other bakery products as dough-based products such as pizza bases and pie crusts, tortillas, wraps, naan, potato soft flatbread ('lompe'), pita bread, and similar products, hot dog bread, hamburger buns, biscuits, taco shells, sweet yeast-containing bakery products, cakes, and ready-to-use flour mixes for baking any of these products.

2.4.2 Salt content in bread and other bakery products

Table 2.4.2-1 shows the salt content that VKM will use for the various foods included as bread and other bakery products. As recommended by NFSA, VKM has used values from Table 3 in *Evaluation of the Intent Agreement for a Healthier Diet 2016-2025*, the evaluation report from the Partnership for a Healthier Diet, an agreement of collaboration between the health authorities in Norway and the food industry (Abel, Paulsen, et al., 2025). For other items (homemade bread, biscuits, sweet products and cakes) values were taken from NFC.

We will estimate the differences between using the specific values in Tabel 2.4.2-1 with 6 different values, and using two values with 0.94 for all bread and breadlike products and also savory biscuts and 1.20 for crisp bread and baguettes and salty biscuits, before we decide what to include in the final calculations.

Table 2.4.2-1 Salt content in industrially produced and homemade bread and other bakery products used in this risk assessment. Source: Abel, Paulsen, et al. (2025), table 3 and NFC.

Food	Salt content, g salt/100 g vare
All types of bread, regardless of their whole grain content[1]	0.94
Baguettes, ciabatta, foccacia[1]	1.29
Rolls, bagels, and soft, round portion breads (Polarbrød)[1]	0.93
Crispbread, and dry bread (inkl flatbrød and taco shell) such as rusks[1]	1.18
Dough-based products such as pizza bases and pie crusts[1]	0.93
Tortillas, wraps, naan, pita bread, and similar products[1]	0.93
Lompe, hot dog buns, and hamburger buns[1]	0.93
Ready-to-use flour mixes intended for baking[1]	0.72
Salt biscuits[2]	2.0
Sweet biscuits and other sweet bakery products with added salt[2]	0.85
Sweet bakery without added salt[2]	0
Homemade bread, regardless of their whole grain content[2].	0.3

Food	Salt content, g salt/100 g vare
Homemade other bakery products will be assigned the same salt content as corresponding industrially produced bakery products, see above.	

[1]Weightet for wholesale.
[2]Recipes from food databases in the national dietary surveys.

Salt content in imported bread and other bakery products is assumed to be equal to products produced in Norway.

2.4.3 Handling of homemade bread and other bakery products

According to data from Norkost 4, approximately 15% of the bread consumed is homemade. Salt used for homemade bread and other bakery products is per definition household salt, and salt in homemade bread and other bakery products will be handled as household salt, see section 2.3. In the Norkost 4 report it is estimated that bread and crisp bread contributes to 1% of the total iodine intake (table 62 in Myhre et al. (2024).

2.4.4 Handling of industrial bread and other bakery products produced in Norway

Baseline measurements from the NFSA show that only a small proportion of Norwegian produced bread is fortified. Salt in Norwegian produced bread and other bakery products will be assigned an iodine content of 0 in the intake estimates at baseline, this also includes imported bread.

In the iodised salt fortification coverage scenarios, salt in bread and other bakery products produced in Norway will be assumed to contain 20 µg iodine per gram salt. Coverage refers to the proportion of the targeted salt that is iodised with 20 µg per gram salt), e.g. 25, 50, 75 and 100% coverage.

2.4.5 Handling of imported bread and other bakery products

Imported bread and other bakery products constitute approximately 20% of all bread products. This estimate is based on external trade statistics and dietary statistics from Statistics Norway (SSB) from 2023. Main countries of origin were Sweden (38%), France (18%), Denmark (12%), Germany (10%). Other countries of origin are Belgium, Poland, Luxembourg, Great Britain and Lithuania (all 3% each). Crispbread was mainly from Sweden (86%).

It is likely that bread imported from countries with mandatory fortification of salt in bread contains iodine in the quantities required by those countries. It is only Denmark which have mandatory fortification of salt among the four main countries of origin with 20 µg iodine per gram salt. However, we do not have information from the dietary surveys on the consumption of imported bread and other bakery products.

According to data VKM has received from NFSA on iodine content in bread and other bakery products including data on country of origin, no bread, and only very few crisp breads imported from Sweden contain iodine. Iodisation levels in imported bread and other bakery products from the other countries of origin are unknown.

Taking all of this into consideration, we have concluded that imported bread will be treated in the same way as bread produced in Norway, see section 2.4.5.

2.5 Iodine intake from food supplements

The NFSA has requested that Iodine intakes are compared to DRVs *with* and *without* contribution from food supplements.

Iodine intake from supplement use in adults (Norkost 4) will be based on reported intake during the registration days. We will use the iodine values for food supplements as reported in the Norkost 4 database (N4).

The contribution to iodine intake from food supplements among adults (Norkost 4) will be estimated based on intakes among participants who report supplement use (users only-approach), provided that the sample size is sufficient to yield reliable estimates.

In VKM et al. (2020) it was found that 4% of the 13-year-old girls (n=14) and 3% (n=9) of the 13-year-old boys in Ungkost 3, reported to use iodine supplements. In 9-year-olds, 4% of the girls (n=13) and 2% (n=6) of the boys reported to use iodine supplements. In 4-year-olds, 4% of the girls (n=8) and 5% (n=12) of the boys reported to use iodine supplements. In Småbarnskost 3, 10% of the 2-year-olds reported to use iodine supplements with at mean iodine contribution of 96 µg/day. In these age groups the sample sizes will not be sufficient to yield reliable estimates for supplement users only.

For pregnant and breastfeeding women, VKM will aim to describe data from the Norwegian Public Health Survey regarding the frequency of use of multivitamin and multimineral supplements, iodine-only supplements, and seaweed-derived supplements.

2.6 Baseline iodine intake and iodine intake in the scenarios

Iodine composition data, household salt, and industrial bread and other bakery products will be updated and constitute the basis for estimating iodine intake at baseline. In the scenario modelling, the coverage percentage for in household salt and/or iodised salt added to industrial bakery products change. The modelling of usual intakes and statistical analyses are described in chapter 3.

The various factors to be considered regarding 1) updated iodine database, 2) household salt and 3) salt in industry bread and other bakery products when estimating baseline iodine intake and iodine intake in the scenarios that have been detailed in sections 2.1-2.5 are summarised in table 2.6-1.

Table 2.6-1: Details to be considered when estimating baseline iodine intake and iodine intake in the scenarios.

	Baseline intake, see section 2.6.1	**Scenarios, see section 2.6.2**	**Source and level of intake data, see section 2.1**	**Notes/ comments**
Iodine from non-fortified sources				
Milk/ dairy products, fish/ fish products, eggs, mineral water, and all other non-fortified iodine sources	All included.	Same as in baseline intake.	Surveys, individual level.	New food composition data for some sources (see section 2.2).
Iodine from breastmilk	Included for children 1 year	Linear increase with maternal iodine intake	Population level (breastmilk intake and BMIC) Individual level (subtraction of other milk)	Breastfed children 1 year of age (45%)
Iodine from fortified sources				
Household salt, see section 2.3	Iodised (5 µg/g salt) and non-iodised salt. Proportions estimated based on Norkost 4 questionaire or SSB dietary statistics.	Iodine set at 20 µg/g salt. Different levels of coverage.	Surveys, individual level.	Salt in homemade bread included as household salt. Approximately 15% of the bread consumed is homemade (see section 2.4.2).
Industrially used salt in bread and bakery products, see section 2.4	Iodine level assumed to be 0	Iodine set at 20 µg/g salt. Different levels of coverage.	Salt from bread in surveys, individual level.	Which food items to be included in the categories bread and other bakery products.
Plant-based alternatives to milk and dairy products, see section 2.2.	New food composition data for some sources, see section 2.4.	Same as in baseline intake.	Surveys, individual level.	

	Baseline intake, see section 2.6.1	Scenarios, see section 2.6.2	Source and level of intake data, see section 2.1	Notes/ comments
Iodised salt in other processed foods, such as sauces, soups, buillons, and ready-made foods, see section 2.2.	Will use iodine values already included in the food database (N4).	Same as in baseline intake.	Surveys, individual level.	
Food supplements				
Iodine from food supplements, see section 2.5.	Supplement and non-supplement users.	Same as in baseline intake	Surveys, individual level.	Few users, particularly among children.

2.6.1 Baseline iodine intakes

Baseline intake refers to iodine intake prior to the implementation of the Iodine Fortification Programme. Baseline iodine intakes will be estimated with and without contribution from food supplements for adults. For more details on food supplement data, see section 2.5.

1) The baseline iodine intakes will be based on iodine intakes from all foods reported in the national surveys. However, we will compile a common iodine database for all surveys with up-to-date iodine content. For products that may already be fortified with iodine, we will use iodine values already included in the N4 food database, except for plant-based alternatives to milk that will be updated with any new values (section 2.2).

   VKM will use breastmilk volumes for for 1-year-olds derived from other studies (section 2.1.2).

2) Household salt (section 2.3), including salt in homemade bread and other bakery products: Total salt intake will be estimated using the national dietary surveys. Household salt will be calculated as a proportion of total salt intake from the national dietary surveys. When estimating baseline iodine intakes, we will assume that a defined proportion of household salt is iodised (section 2.3.2.1), while the remaining fraction is non-iodised. For iodised household salt included in the baseline intakes, an iodine concentration of 5 µg iodine per gram of salt will be applied. Approximately 15% of the bread and other bakery products consumed will be handled as homemade (section 2.4.2).

3) Salt in industry bread and other bakery products (section 2.4):
   The definition of “bread and other bakery products”, including the specific food items classified within these categories, is provided in section 2.4. The category of industry bread and other bakery products includes items produced with both fortified and non-fortified salt, and may be produced in Norway or imported from other countries.

   a) Bread and other bakery products produced in Norway (section 2.4.4):
   Baseline measurements from NFSA show that only a small proportion of Norwegian produced bread is fortified. Salt in Norwegian produced bread and other bakery products will be assigned an iodine content of 0 in the intake estimates at baseline.

   b) Imported bread and other bakery products (section 2.4.5):
   Imported bread and other bakery products will be handeled as bread and other bakery products produced in Norway.

Table 2.6.1-1 shows the levels of iodine in household salt and salt in bread and other bakery products that will be used to estimate baseline intakes.

Table 2.6.1-1 Levels of iodine in salt in the food groups included in the Iodine Fortification Programme at baseline intakes.

Food groups included in the Iodine Fortification programme	Iodine in salt at baseline intakes	Proportion of iodized salt
Iodised household salt, including salt in homemade bread and other homemade bakery products	5 µg	Based on SSB or Norkost 4 questionnaire
Iodised salt in Norwegian or imported industrial bread and other bakery products	0	0

2.6.2 The iodised salt fortification coverage scenarios

VKM has been requested to evaluate different scenarios for fortification coverage. Coverage refers to the proportion of the targeted salt that is iodised with 20 µg iodine per gram salt, (e.g. 25, 50, 75 and 100% coverage) of household salt and bread and other bakery products with iodised salt. In the fortification coverage scenarios, household salt and salt in industrially produced bread and other bakery products will be assigned equal coverage percentages. In other words, for coverage of 25%, we will implicitly assume that 25% of the household salt plus 25% of salt in bread and bakery products is fortified.

The iodine intake in the scenarios will be based on the baseline intake (see section 2.6.1). However, in the scenarios, the iodine level in salt will be set to 20 µg per gram salt. The scenarios will be estimated with and without contribution from food supplements for adults. For more details on food supplement data, see section 2.5.

1) The iodine intakes in the scenarios will be based on iodine intakes from all foods reported in the national surveys. We will compile a common database for all surveys with up-to-date iodine content (section 2.2). Identical with the common iodine database in baseline intakes.

2) Household salt (section 2.3), including salt in homemade bread and other bakery products: Total salt intake will be estimated using the national dietary surveys. Household salt will be calculated as a proportion of total salt intake from the national dietary surveys. When estimating the scenarios, we will assume that various percentages of household salt is iodised (the coverage percentages). For iodised household salt included in the scenarios, an iodine concentration of 20 µg iodine per gram of salt will be applied. Approximately 15% of the bread and other bakery products consumed will be handled as homemade (section 2.4.2).

3) Salt in industry bread and other bakery products:

   a) Bread and other bakery products produced in Norway (section 2.4.4):
   In the iodised salt fortification coverage scenarios, salt in bread and other bakery products produced in Norway will be assumed to contain 20 µg iodine per gram salt. Coverage refers to the proportion of the targeted salt that is iodised with 20 µg per gram salt), e.g. 25, 50, 75 and 100% coverage.

   b) Imported bread and other bakery products (section 2.4.5):
   Imported bread and other bakery products will be handled as bread and other bakery products produced in Norway.

Table 2.6.2-1 shows the levels of iodine in household salt and salt in bread and other bakery products that will be used to estimate the scenarios.

Table 2.6.2-1 Levels of iodine in salt in the food groups included in the Iodine Fortification Programme in the scenarios.

Food groups included in the Iodine Fortification Programme	Iodine in salt in the scenarios	Available for fortification in 0-100% coverage scenarios
Iodised household salt, including salt in homemade bread and other homemade bakery products	20 µg	Household salt
Iodised salt in industrial bread and other bakery products	20 µg	Iodised salt in Norwegian and imported, industrial bread and other bakery products

2.6.3 Inclusion of iodine from breastmilk

In the VKM et al., (2020) report calculations iodine from breastmilk in 1-year olds was not included. In the forthcoming risk assessment, VKM will therefore estimate and include the iodine contribution from breastmilk for 1-year-old breastfed children (see section 2.1.2).

Breastmilk typically has a lower iodine concentration than infant formula and animal milk, however, breastmilk may for some children be a substantial contributor to total iodine intake.

2.6.3.1 Iodine from breastmilk in baseline intakes

Breastfeeding at this age ranges from occasional "comfort feeding" to substantial meals, and although frequency data (how often the child is breastfed) are available in Spedkost 3, volume and iodine concentration data are lacking.

For breastmilk volumes and iodine content in breastmilk, VKM will use recent data from studies in Norway and abroad, see section 2.1.2. For breastfed children identified from Spedkost 3, age-specific breastmilk estimates will be multiplied with mean BMIC from a Norwegian sample.

2.6.3.2 Iodine from breastmilk in the scenarios

Iodine concentration in breastmilk (BMIC) largely reflects the mother's iodine status. In the iodised salt fortification coverage scenarios, the increase in maternal iodine intake should be reflected in the iodine concentration of breastmilk. VKM will assume a linear relationship between these factors; thus, a 20% increase in maternal iodine intake is expected to result in approximately a 20% increase in the iodine concentration of breastmilk. This assumption enables scenario modelling to be linked directly to dietary intake data for mothers.

To operationalise this, the modelling will draw on iodine intake estimates for women aged 18–49 years in Norkost 4, as this age group represents the most relevant population of mothers of 1-year old children. Any change in iodine intake within this group under the various fortification scenarios will therefore be transferred proportionally to the estimated iodine concentration of breastmilk.

In the scenarios where iodine fortification of salt in foods (e.g. household salt or bread) is implemented, the model will:

- Quantify the increase in maternal iodine intake under each scenario, based on her estimated dietary intake in Norkost 4;
- Adjust the iodine concentration in breastmilk by the same relative percentage increase; and
- Estimate the child's iodine intake from breastmilk using the updated concentration.

All breastfed children will be assumed to have the same breastmilk volumes in both baseline intake and scenarios.

2.7 Established DRVs for iodine

For this risk assessment we will use the provisional average requirements (p-AR) for iodine established by the Nordic Nutrition Recommendations (Blomhoff et al., 2023) and adapted by the Norwegian Directorate for Health (Helsedirektoratet, 2024) as a cut-off reference value for comparison for insufficient intake. The average requirement (AR) is the daily nutrient intake level that is suggested to meet the requirements of half of the individuals in a particular life-stage group. The provisional AR, which is an approximation of AR, has larger uncertainty than AR. It is calculated by multiplying adequate intake (AI) by a factor of 0.8. The provisional AR can be used when an AR cannot be determined (Blomhoff et al., 2023).

As cut-off value for comparison for excessive intake we will use the tolerable upper intake level (UL) set by the Scientific Committee on Food (SCF, 2002), endorsed by EFSA, and later confirmed by VKM (VKM et al., 2020). UL is the maximum level of total chronic daily intake of a nutrient (from all dietary sources) which is not expected to pose a risk of adverse health effects to humans (EFSA, 2024).

The critical endpoint for determining the p-AR according to NNR (2023) is the prevention of impaired thyroid function, assessed through changes in markers such as TSH, thyroglobulin (Tg), thyroid hormone concentrations (T4 and T3), and thyroid volume.

The critical endpoint for the UL as defined by SCF (2002) is thyroid dysfunction, specifically iodineinduced disturbances such as elevated TSH and hypo or hyperthyroidism.

In 2020, VKM conducted a systematic review of the literature and proposed retaining the UL from SCF for both adults and children. The literature search for adverse health effects from excessive iodine intakes aimed to retrieve new publications from the year 2000 onwards in order to potentially re-evaluate the existing ULs (VKM et al., 2020). Evidence from a dose-response study from 2012 (Sang et al, 2012) showed that negative health effects may appear at an iodine intake of 800 µg/day in adults, which is lower than the established LOAEL by SCF of 1800 µg/day. Despite this, VKM suggested to maintain the UL set by SCF in 2000 of 600 µg/day for adults. Owing to the larger sample size and longer follow-up period in the 2012 study, a lower uncertainty factor was applied (UF of 1.3 compared with 3 used by SCF in 2002), which resulted in an UL of 600 µg/day for adults. In children, recent studies suggested that adverse health effects may occur at intakes below the existing ULs from SCF, which was derived from studies in adults. However, due to uncertainties of the new studies (only cross-sectional design), the ULs established by SCF in 2002 were retained for all age groups.

Both p-AR and UL are established for all relevant age groups, see table 2.7-1.

Table 2.7-1 p-ARs and ULs for iodine used in this assessment for various age groups, µg/day.

Population	p-AR	UL
Age groups	**Both sexes**	**Both sexes**
1- and 2-year-olds	80	200
4-year-olds	80	250
9-year-olds	80	300
13-year-olds	100	450
18-29 years	120	600
30-49 years	120	600
50-80 years	120	600
Pregnant, 1. trimester	140	600
Pregnant, 2. trimester	160	600
Pregnant, 3. trimester	160	600
Lactating	160	600

3 Methods for the intake estimates of iodine

3.1 Data cleaning and preprocessing: national dietary surveys

No specific data cleaning or preprocessing will be carried out beyond what has been performed for the analysis in the main reports on the respective surveys.

3.2 Modelling of iodine intake estimates and scenarios

We will use a multivariate linear mixed model (LMM) approach with multiple fixed effects to estimate usual intake of iodine before launching of the Iodine Fortification programme (baseline intake), and to simulate intakes of iodine from fortified salt in bread and other bakery products and household salt (referred to as "salt-available-for-fortification") under various fortification scenarios.

Multivariable LMM will be applied to two dependent variables; daily iodine intake and 'salt-available-for-fortification' values, calculated for all days and individuals in all surveys. A hierarchical approach will be used to decompose variability into within-individual variation in intake (i.e. day to day variation implemented as residuals), between-individual variance and covariance between intake of iodine and salt (implemented as individual level random effects with covariance), except in 1- and 2-year-olds with FFQ data. For the surveys we will include several fixed effects to adjust for potential bias in the distribution of age, sex, reporting weekdays, level of education and region of residence (see table 3.2-1). Distributions for age, sex, level of education and residence used in response bias adjustment are available from Statistics Norway. Not all covariates are relevant in the different surveys (e.g. season is only included for Norkost 4 which covered an entire year, and weekdays are not included for Småbarnskost 3 and Spedkost 3 based on FFQ data).

For the data on 1- and 2-year-olds we do not have daily observations and the estimation of usual intake is performed as part of the dietary assessment method – parents are asked about the child's usual intake, keeping the last 14 days in mind when completing the FFQ. Models applied to these data will not include day-to-day variability but will try to capture individual level covariance between iodine intake and salt-available-for-fortification. In principle a LMM with two dependent variables (iodine intake and salt-available-for-fortification) can be applied with individual level random covariance effects and residual independently, but this is not guaranteed to be successful (see section 3.2.1). If these models have identifiability issues, models without individual level random effects will be applied to FFQ data.

Table 3.2-1 Model specifications for linear mixed models (LMMs).

Survey (method)	Model	Fixed effects or covariates	Random effects and residuals
Norkost 4: adults (2*24 hour recalls)	LMM, hierarchical	~Sex + Age + Education.High+Region+Weekday+Month. To be considered: Day of week (7 levels) or binary (weekday vs weekend Fri-Sun), Energy intake and/or misreporter (yes/no). Iodine supplement use (yes/no).	Random effects: covariance food iodine and salt-available-for-fortification. Residuals: day-to-day variation in registration days.
Ungkost 3: age 4, 9, 13 years (food diaries, 4 days)	3 separate LMM	"~Sex + Education.High(parental)+Region+Weekday". To be considered: Day of week (7 levels) or binary (weekday vs weekend Fri-Sun: Wednesdays are over-represented), Energy intake and/or misreporter (yes/no). Iodine supplement use (yes/no).	Random effects: covariance food iodine and salt-available-for-fortification. Residuals: day-to-day variation in registration days.
Småbarnskost 3: age 2 years (FFQ)	LMM	Covariates: sex, parental education. To be considered: Energy intake and/or misreporter (yes/no).	Random effects: covariance food iodine and salt-available-for-fortification. Residuals: remaining variability in reported intakes.
Spedkost 3: age 1 year (FFQ)	LMM	Covariates: breastfeeding (yes, no), parental education. To be considered: Energy intake and/or misreporter (yes/no).	Random effects: covariance food iodine and salt-available-for-fortification. Residuals: remaining variability in reported intakes.

Education level: In Norkost 4, the education level will be set to 1 for respondents with a college degree and 0 otherwise. For Ungkost 3, Småbarnskost 3, and Spedkost 3 information on parental education will be used, setting the variable to 1 if at least one parent has a college degree.

To evaluate some of the assumptions on model structure and data input we will perform several sensitivity analyses, see section 3.2.4.

3.2.1 *Intakes prior to the Iodine Fortification Program – baseline intakes*

The main models applied to Norkost 4 data will include all individuals and assume a random effect of daily intake of iodine and salt-available-for-fortification. However, this between-individual variability could in principle be larger or smaller for different subgroups. Since both baseline intake and intake under scenarios should be split by population groups in table 1.3-1 we will also fit a LMM separately for these age and sex groups allowing for the random effects, i.e. the between-individual variability, to be different between the models. They will be briefly compared and if they show a markedly better fit, we will use separate models for the scenarios for the different groups.

All fitted models will be used to estimate distributions of individual level baseline usual (long-term) intake of iodine adjusted for response bias. Using fitted parameters, we will simulate 365 individual days of iodine intake for 100 000 individuals within each population group (table, 1.3-1). The distribution of simulated intakes will be compared with p-AR and UL (table 2.7-1) to estimate proportion of individuals in each group above UL and below p-AR.

3.2.2 *Scenario analyses*

All scenario analyses will be based on the fitted models. In addition to simulating usual intake of iodine from the diet, we will also simulate usual intake of salt-available-for-fortification for all subgroups in table 1.3-1. By multiplying the simulated intake of salt with level of coverage of fortification we will get predicted distribution for long-term intake under different fortification scenarios and can estimate the proportion of individuals in each group above UL or under p-AR.

3.2.3 *Food supplement use*

Iodine intake is highly impacted by use of food supplements which can lead to a low fraction of individuals with very high intake, and fewer with a very low intake. To attempt to quantify this impact and analyse how fortification scenarios impact user vs non-users of food supplements we will calculate iodine intake with and without supplements. We will apply separate LMMs for both datasets and compare their baseline intake.

We will also if needed use information from the Norkost 4 Questionnaire (frequencies/propensities) to identify users of iodine supplements or seaweed and kelp products.

3.2.4 *Sensitivity analyses*

Some uncertainties in the assessment (see chapter 6) related to the estimation of intake and modelling approach will be addressed with quantitative sensitivity analyses. These analyses will be performed for the 0% (baseline intake) and 100% fortification coverage scenarios. The impact will be assessed by comparing the proportions below p-AR and above UL in the main analysis with proportions resulting from the sensitivity analyses.

The following quantitative sensitivity analyses have been planned, but are not limited to:

Misreporters of energy intake: The analysis will exclude individuals identified as energy misreporters (section 3.3.1). We will also investigate the feasibility of including misreporters as a fixed effect in the main model to compare the predicted intakes in adequate reporters with that of misreporters (under- and over-reporters).

Estimation of total salt: Total salt (section 2.3.1) will be estimated using external biomarker data as sensitivity analyses. In adults, VKM will use urinary sodium excretion from the Tromsø 7 study. In children age two years, VKM will try to use data from the National monitoring program on iodine. A subsample of children (age two years) has two spot urine samples which have been used by the monitoring program to estimate usual salt intake (currently unpublished data).

Estimation of household salt: The analysis will assess the impact of changing the proportion of household salt. Reviewed literature suggest that household salt may constitute from 5% to 15% of total salt in countries assumed to be comparable to Norway. In the main analysis, 10% will be used. Other proportions (5% and 15%) will be applied to total salt intake in the main analysis based on national dietary surveys.

Usual intake modelling: we will investigate the feasibility of using established methods and functions (SPADE multipart model, and the NCI method) for adults with 2*24-hour recall data (Norkost 4 survey).

3.3 Addressing under- and overreporting in the dietary surveys

3.3.1 Goldberg and Black cut-off method

Validation studies have been conducted for the versions of the FFQs (Andersen et al., 2003; Andersen et al., 2004; L.F. Andersen et al., 2009) and 4-day food diary (Lillegaard & Andersen, 2005; Lillegaard et al., 2007) used in the first rounds of the national dietary surveys. The methods have been modified for later rounds based on the validation results, new foods on the market, and transition from paper-based to web-based methods, and some aspects have been validated for the revised versions (Kristiansen, Laugsand Lillegaard, et al., 2013; Kristiansen, Lillegaard, et al., 2013; Lillegaard et al., 2012; Medin et al., 2015; Medin et al., 2016; Medin et al., 2017). These studies show that the first FFQs used in 1- and 2-year-olds tend to overestimate the intake of energy, and the intake of most foods and nutrients compared with a 7-day weighted food record. Of note, the FFQs have not been validated for iodine intake specifically. The 4-day food diary used in children and adolescents (age 4, 9, 13 years) has been found to underestimate energy intake, and the underestimation increases with age and the number of recording days (Lillegaard & Andersen, 2005; Lillegaard et al., 2007).

VKM will address potential over- or underestimation of iodine intake in the national dietary surveys for adults and children by identifying misreporters with Goldberg and Black cut-off method (Black et al., 1991; Goldberg et al., 1991). Goldberg and Black cut-off method is a well-established method for identifying misreporters of energy intake in dietary surveys based on energy intake and expected energy expenditure. VKM will use this method to identify misreporters in all included age groups, and the effects on iodine intakes, as previously done for Ungkost 3 (Medin et al., 2020).

Because weight stability is a central assumption underlying the Goldberg and Black method, it is challenging to interpret findings in infants, children and adolescents, who are undergoing normal growth and therefore not expected to maintain stable body weight.

To investigate the applicability of the Goldberg and Black cut-off method in dietary surveys conducted in children, we will perform a search in PubMed to identify studies that either discuss the suitability of the Goldberg and Black variation factors for children or have applied the cut-off method in samples including children.

We will identify both underreporters and overreporters and conduct sensitivity analyses (section 3.2.4) that exclude these misreporters.

3.3.2 Urinary iodine data

VKM has been strongly encouraged by stakeholders to address potential over- or underestimation of iodine intake derived from the national dietary surveys by using data on urinary iodine, and to attempt to calibrate intake from these dietary surveys based on urinary iodine. As part of drafting the protocol, VKM has considered these suggestions based on *a priori* knowledge and reviewed literature.

A priori it can be established that calibration with internal validation data is not possible because the national dietary surveys do not include biomarkers. Calibration of an intake distribution against external data is more challenging as there is no formal method established to VKM's knowledge and the data should be representative of the general population.

Studies with data suitable for external calibration were not found based on the reviewed literature. VKM has investigated available data by compiling a list of 31 studies from Norway reporting on urinary iodine levels in different study populations. VKM included 12 studies where the iodine levels could be interpreted as or converted to iodine intake for comparison with dietary surveys (similar age groups and time frame). VKM followed recommendations from the WHO (2024) when converting data on urinary iodine concentration (UIC) into intake. Adjustment for urinary creatinine to correct for urinary volume was therefore an inclusion criterion for studies reporting UIC. Some included studies also assessed dietary intake of iodine, and VKM registered if the dietary assessment instrument was the same as that used in the national dietary surveys, or a different instrument. VKM has compared median iodine intakes from urine in the included studies to median intakes from the national dietary surveys. Methods for the compilation and comparisons, and forest plots of the results (Figure 1 to 6) are found in Appendix 1. These comparisons should not be interpreted as validation of the dietary assessment methods but indicate if iodine intake from dietary surveys is consistently higher or lower than intake in biomarker studies at the group level. Based on the results, VKM do not plan to calibrate data from the national surveys for the following reasons:

Most biomarker studies (Appendix 1) rely on single spot urinary iodine measurements, which do not support prevalence estimates but can be used to assess iodine status at the population level from the observed median. These studies do not support reliable estimation of individual usual intakes and tail probabilities of low or high intakes, which is most relevant to risk assessment. Furthermore, most biomarker studies are based on regional samples, not national, and many are small.

Iodine intake from the included biomarker studies do not differ from the national dietary surveys in a manner that is consistent with the validation studies of the national dietary surveys. For example, the FFQ used in 2-year-olds over-report energy intake, most nutrients and foods compared with a 7-day weighed record (but of note, iodine intake has not been validated) (Andersen et al., 2004; L.F. Andersen et al., 2009). But when compared with iodine intake based on urine from 2-year-old participants in the national monitoring program (unofficial results until publication), the median FFQ intake is higher in girls but lower in boys.

In summary, no robust calibration of intake in the national dietary surveys may be conducted based on identified biomarker data. Calibration against unrepresentative data or a small data set could introduce new bias and/or uncertainty. Even if suitable data should become available soon, developing a method for calibration is still a comprehensive task that cannot be carried out within the given time frame of the current risk assessment. However, the included biomarker studies may support discussions of intakes and uncertainties in groups assumed to be at risk of low or high iodine intakes (such as vegans or seaweed consumers) where national dietary surveys do not provide sufficiently large samples for analysis.

3.4 Usual intake estimation

Both the NCI method and SPADE program (planned sensitivity analyses, section 3.2.4) are well established and scientifically robust approaches for modelling usual dietary intake, based om short-term methods. However, we have concluded that the in-house model from the VKM et al. 2020 report is more adaptable to the objectives of this assessment and the specific data structures, allowing for individual level covariance, which is essential for modelling correlations between different dietary sources of iodine. These challenges are amplified in the Norwegian context, where three different dietary assessment methods (24-hour recalls, food diaries, and FFQs) must be accommodated, adding complexity to the modelling framework. This choice reflects considerations of practicality and data compatibility.

3.5 Estimation of iodine sources in the diet

VKM is requested to describe how the sources of iodine change in the different population groups at different coverage levels of the use of iodised salt in industrially produced bread and other bakery products. VKM is requested to provide information on the proportion of iodine that comes from:

- Naturally occurring sources (milk, fish, eggs, etc.)
- Food supplements
- Fortified salt (household or industrial) and plant-based milk alternatives

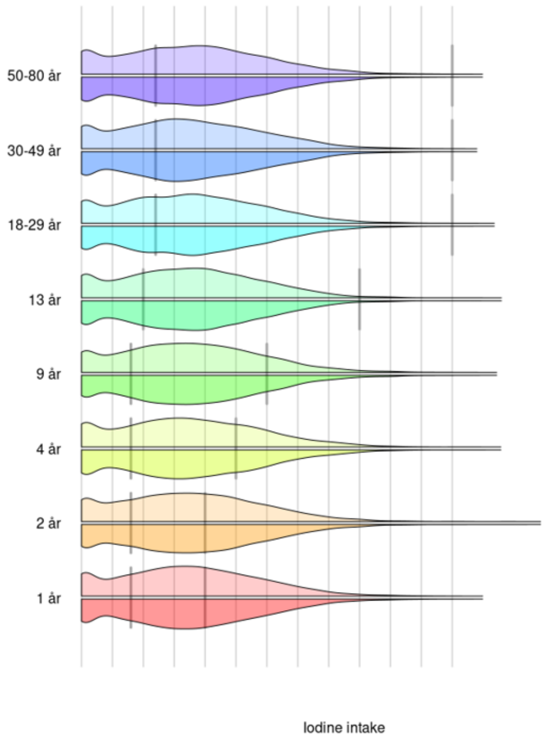
Sources of iodine will be estimated for baseline intakes in all population groups, and for the following iodised salt fortification coverage scenarios; 25%, 50%, 75%, and 100%. Iodine sources in the diet will be estimated deterministic, using observed individual means as reported in the dietary surveys.

4 Presentation of data

4.1 Presentation of main results

Results will be presented for sex and age categories for baseline intakes and the different iodised salt fortification coverage scenarios (e.g. 25, 75 and100%). The 1-year-olds will not be separated by sex but by breastfeeding status. In adults, results will be presented with and without the contribution from iodine-containing supplements, and in children and adolescents only results including contribution from supplements will be presented.

We will present violin plots of iodine intake for both baseline intakes and the 100% iodised salt fortification scenario, stratified by sex and age, accompanied by tables showing the proportions below the p-AR and above the UL, as illustrated in figure 4.1-1.



P(<AR)	P(>UL)	p05	P50	P95

Figure 4.1-1. Figure example for violin plot and tables that will be presented for baseline intakes and 100% iodised salt fortification scenario. The two vertical lines for each age group, will represent p-AR and UL.

Additionally, we will present figures for each age groups that show proportions below the p-AR and above the UL throughout the baseline intakes and in the changing scenarios.

4.2 Presentation of sources to iodine

The NFSA requests VKM to describe how the dietary sources of iodine change in the different population groups at varying coverage levels of iodised salt use in industrial bread and other bakery products. We have been requested to identify the following sources to iodine:

1. Naturally occurring sources (e.g. milk, fish, eggs)
2. Food supplements
3. Fortified salt (household or industrial) and plant-based milk alternatives
4. Sweet and unsweetened bakery goods

Iodine intakes from points 1 and 2 will remain constant in baseline intakes and the scenarios, whereas point 3 and 4 will increase linearly. We will present data for baseline intakes and the scenarios for sources to iodine.

5 Criteria for evaluation of risk

In this chapter, we will give a description of how we plan to characterise the risk.
In the mandate, VKM has been requested to assess the risk of insufficient intake (below the p-AR) and the risk of excessive intake (above the UL), as well as to evaluate the Iodine Fortification Programme's effect on iodine intake in various population groups, including assessing population groups that will benefit from the measure or that may be at risk of excessive intake.

To evaluate the risk of both low and high iodine intakes, VKM will use the p-AR and the UL as two distinct reference values, each applied within its respective scientific framework. The p-AR will be used to assess the risk of inadequate intake, while the UL will be used to assess the risk of excessive intake. VKM will not compare the p-AR and UL with each other in any conceptual or analytical sense.

This approach is necessary because the p-AR and UL are not comparable reference values. They originate from different scientific frameworks (nutritional adequacy vs. toxicological safety) and address different types of risk (deficiency vs. excess). Importantly, the p-AR represents an intake level estimated to meet the nutritional requirements of approximately half of individuals in a group, whereas the UL represents an upper intake threshold below which adverse effects are unlikely to occur.

Furthermore, VKM will assess the risk in light of population groups that are particularly vulnerable to either low or high iodine intake.

5.1 Evaluating risk of low intakes

For evaluating risk of low intakes, VKM will use the AR cut-off method described in the WHO-report Prevention and control of iodine deficiency in the WHO European Region from 2024 (WHO, 2024). VKM will examine the proportion within each group that falls below the p-AR, and assess the prevalence of inadequate iodine intake in the groups. That is, the prevalence indicating a (relatively) high probability of inadequate intake.

Criteria that will be applied:

- If <3% of a group falls below the AR, the group's intake is considered adequate, meaning a (relatively) low probability of inadequate intake.
- If more than 3–10% of a group has an intake below the AR, iodine deficiency may be considered a public health concern in the studied population.

The magnitude of the problem increases with the proportion below the p-AR. There is, in any case, a continuum of uncertainty in dietary intake data (likely greater than a few percentage points).

The p-AR is established on a different basis than an AR and is therefore associated with greater uncertainty; see section 2.7 and chapter 6. We will therefore interpret these results with extra caution.

5.2 Evaluating risk of high intakes

For the evaluation of risk of high intakes, VKM will assess the proportion within each group whose intake exceeds the UL.

At habitual intakes above the UL, the risk of adverse effects increases as intake levels rise. The specific intake at which an individual will develop adverse effects is not known, but the UL serves as a practical upper bound for the maximum tolerable usual intake for individuals. Because the UL is established to protect the most sensitive members of the population—and it is not possible to identify who these individuals are—it must be interpreted as applying to everyone, even though some people may regularly consume nutrients at or slightly above the UL without experiencing harm. (EFSA, 2024).

Usual intake distributions (e.g. percentiles) allow estimation of the proportion of the population that exceeds the UL and is therefore at potential risk of adverse effects.

IOM (2000) suggest considering the following factors when assessing the risk of high intakes, e.g:
– the accuracy of the intake data
– the proportion of the population with intakes consistently above the UL
– the seriousness of the adverse effect
– the extent to which the adverse effect is reversible when intake is reduced below the UL.

Consequently, the UL will be treated as an absolute safety limit for avoiding excessive intakes, and VKM will consider the factors listed above, and also elaborate on the uncertainty factor inherent in the UL for iodine.

5.3 Population groups most vulnerable to low and high iodine intake

Since some population groups are likely to include individuals with intakes below the p-AR, while others may include individuals exceeding the UL, it is relevant to consider whether population groups can be weighed against one another.

The health consequences of impaired thyroid function vary across the life course, with particularly vulnerable developmental windows during pregnancy, infancy, childhood, and adolescence, as thyroid hormones are essential for brain function and development, growth, and metabolic regulation.

We will interpret the significance of not being within the p-AR-UL range with care. Important factors we will consider include how far outside the range the observations lie, and how vulnerable the population is to fluctuations in iodine nutrition and the potential consequences of thyroid disruption at that life stage.

It is outside the scope of this assignment to evaluate the evidence for any health outcomes potentially associated with low or high iodine intake. The mandate is limited to assessing intake in relation to established reference values for iodine. The results of the previous VKM benefit and risk assessment of iodisation of salt, and recent meta-analyses do not suggest that mild-to-moderate deficiency is associated with disruption of thyroid hormone production or clinical outcomes (Dineva et al., 2020; VKM et al., 2020; Aarsland et al., 2025).

6 Uncertainty

A separate chapter in the report will address uncertainty. We will identify, characterise and if possible, quantify uncertainties related to different aspects of the assessment.

In this assessment, data are available from different sources and at different levels, which has implications for overall uncertainty. These structural and methodological differences between data types, may represent a source of uncertainty in both intake estimates and scenario modelling.

To characterise the uncertainty, a more detailed analysis will be conducted of the dietary intake of individuals exceeding the UL, and those below the p-AR in the group of 1- and 2-year-olds. This will include an assessment of reported energy and food intake, identification of key dietary sources to iodine, and an evaluation of the contribution from iodine-containing salt in bread.

Sensitivity analyses will be conducted to assess the influence of key assumptions and selected parameters on the results. Table 6-1 identifies and describes possible uncertainties, and approaches to address these in the risk assessment. Impact of the uncertainty factors and whether they have a substantial significance for the estimated iodine intake cannot be assessed during the writing of the protocol, therefore, the approach to addressing the uncertainties may change.

For pregnant and breastfeeding women, the available data are insufficient for conducting exposure calculations or a comprehensive risk assessment. VKM will therefore consider whether frequency data from the Norwegian Public Health Survey on key iodine sources and dietary supplement use can serve as supplementary information to inform the assessment of iodine intake and related uncertainties in these population groups.

Table 6-1 Uncertainties and suggested approaches to quantify or address them.

Uncertainties		
Identification	**Characterisation**	**Suggested approach**
Dietary assessment methods	The national dietary surveys are based on different dietary assessment methods, which vary in their ability to capture consumption of iodine-containing foods.	The inherent uncertainties associated with the different methods will be discussed in the risk assessment. Uncertainties associated with the absolute iodine intake levels in all groups will be described in the uncertainty chapter and reflected in the discussion and conclusion. Analysis will be conducted among 1- and 2-year-olds exceeding the UL or below the p-AR, including reported energy and food intake, key dietary iodine sources, and the

Uncertainties		
Identification	**Characterisation**	**Suggested approach**
		contribution of iodine-containing salt in bread.
Different years of data collection	The data collection differs from 2014 for Ungkost 3 to 2021-22 for Norkost 4. Food habits will have some changes over the years. Changes in food habits can have an impact of iodine rich foods, bread intake, and supplements use.	We have used one updated database for iodine values for alle three surveys, but we are not able to modify changes in food habits.
Mis-reporters	Iodine and bread might be over- or underreported in the national dietary surveys.	Sensitivity analyses excluding mis-reporters of energy for relevant groups and scenarios will be conducted. Other measures for iodine nutrition such as UIC, and other biomarkers may be used in discussion of uncertainty.
Food composition data	Iodine content in white marine fish have large variation within and between species.	The impact of using updated iodine values for white fish (e.g., low, median, and high) will be evaluated.
Food composition data	Amount of fish in recipes used for fish products will vary between the three different food databases used.	The impact of varying the fish content in fish product recipes will be evaluated and presented if it has substantial impact on the estimates.
Imported bread	Approximately 20% of all bread sold in Norway is imported. Imported bread may contain iodised salt in current production, which would lead to an underestimation of baseline iodine intake, where this is set to zero. In the fortification scenarios, imported bread will be treated in the same way as bread produced in Norway which may overestimate iodine intake if imported bread use non-iodised salt.	Intake estimates will be interpreted considering known or potential under- and overestimation. Data from the Norwegian Food Safety Authority may be considered as a source of supplementary information to further clarify this uncertainty.
Other iodine sources with general permission	General permission for iodine fortification is granted for plant-based alternatives to milk and for salt used in bouillons, sauces, soups, and readymade products. These fortified foods may not be represented in the NFC databases,	Intake estimates will be interpreted considering known or potential under- and overestimation. Data from the Norwegian Food Safety Authority may be considered as a source of supplementary

Uncertainties		
Identification	**Characterisation**	**Suggested approach**
	and possible underestimate baseline intake.	information to further clarify this uncertainty.
Estimation of total salt intake	The national dietary surveys will be used to estimate total salt, which may underestimate the salt intake.	Sensitivity analyses will be conducted using 24-hour urine excretion data from Tromsø 7 in adults and the national monitoring in 2-year-old children.
Estimation of household salt	A proportion of 10% of total salt will be used, which may over or underestimate.	Sensitivity analyses using different proportions will be evaluated during the risk assessment.
Modelling	In house method	The NCI method for selected scenarios in adults will be evaluated as sensitivity analyses. Strengths and weaknesses with different methods will be evaluated.
Subgroups	Subgroups at risk of low or high iodine intakes may be too small to support intake modelling.	The number of individuals in each sub-group will be counted, and we will evaluate whether their mean or median iodine intake is above or below that of the total population. Other measures for iodine nutrition such as UIC, and other biomarkers may be used in discussion of uncertainty related to subgroups. Data from NHUS may be used to provide supplementary information on dietary supplements and key iodine sources among pregnant and lactating women.
Evaluation of risk	The criteria from WHO 2024 is associated with large uncertainties and more data are needed to define the criteria. DRVs: Provisional AR (pAR) carries greater uncertainty than values for the average requirement (AR) and is used when an AR cannot be set. Since both the provisional AR (pAR) and the cut-off used to determine whether the proportion below pAR is of concern are subject to substantial uncertainty, the total uncertainty will increase substantially.	Uncertainties and the robustness associated with the evaluation of risk will be discussed in the risk assessment.

Uncertainties		
Identification	**Characterisation**	**Suggested approach**
Dietary supplements	Iodine intake in children and adolescents will only be calculated with supplements, since there are few reported supplement users. The data from Ungkost are from 2015 and the use of supplements may have changed.	Intake estimates will be interpreted considering known or potential under- and overestimation. Data to explore supplement use in adolescents may be evaluated to explore potential under of overestimation related to supplement use.
Iodine from breastmilk	Age-specific, group-level estimates for breastmilk volume will not capture variation between children and intake may be over- or underestimated. There is also substantial variation in breastmilk iodine concentration (BMIC), but due to limited data, a mean BMIC from a Norwegian sample is applied, which may not reflect true population variability, or the specific BMIC for this age-group.	The uncertainty regarding both the variability and precision of the estimated iodine intakes will be discussed and considered when interpreting the results for breastfed one year old children.
Model structure and random effects	The structure of the models applied to estimate baseline intake and intake under scenarios will impact the estimates.	Impact of all variables will be evaluated by their estimated parameter values. Norkost 4 will be modelled both as one model for all individuals and three separate models for age groups in table 1.3-1. This will allow the groups to have different structure and magnitude of random effects.

7 Permission to use data from the national dietary surveys/ data managment

The VKM secretariat will apply for access and permissions to use data from the three national dietary surveys Spedkost/Småbarnskost 3, Ungkost 3, and Norkost 4 for this project. The data have status as sensitive and will therefore be stored and analysed on the platform TSD (Services for sensitive data) at the University of Oslo.

Necessary software (R, preferably latest version) must be available on the platform as well as possibilities for installing R packages.

We will perform our analysis in TSD "Services for sensitive data (TSD)" hosted by University of Oslo, service for high security data storage and computing. No individual data will be exported from the TDS server and only aggregated data will be presented.

Upon completion of the project, all data stored in TSD will be securely deleted and project access will be terminated, and the code will be exported to Zenodo or GitHub for archiving.

7.1 Variable specification

VKM has applied for access and permission to use personally identifiable data: Sex, age, county, country of birth, education, height, weight, and health issues / allergies / diet-related conditions from the national dietary surveys, all foods, energy, sodium, salt, and iodine as well as respons to questionnaires related to frequency of consumption of fish, milk/ milk products, egg, food supplements, energy restrictions in the diet/ weight reduction goals, and levels of physical activities.

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APPENDIX 1 Urinary iodine data

To compare estimated iodine intake from the national dietary surveys with estimated iodine intake from urine data, VKM compiled 31 studies from Norway with data on measured urinary iodine. The studies were compiled from a review by Henjum et al. (2019) (publications 1.1. 2016–31.7.2018) and by snowballing. The 31 studies were published from 2003 to 2026, with urine data collected from 1999 to 2023. The 31 studies were screened and 12 were included according to the eligibility criteria presented below (Table A-1). The criteria were set to identify studies where iodine intake has been estimated, or where VKM can estimate daily iodine intake from UIC accounting for urine volume, or 24-hour urine samples (UIE) according to WHO (2024). The included studies were mapped to the different national dietary surveys by age of participants and year of data collection. The main study exclusion reasons were lack of adjustment for hydration status by the urine creatine concentration (UCC), or the year of data collection. In adults, Norkost 4 iodine intake was compared to intake in biomarker studies conducted after Norkost 3 (year 2010) to limit the influence of dietary changes over time (e.g. about 10% reduction in iodine intake from Norkost 3 to Norkost 4). In five biomarker studies that only reported the ratio of UIC to creatinine, reference values for creatinine excretion were selected to estimate the 24-hour urinary iodine excretion (UIE). Some results for heterogenous groups (e.g. vegetarians combining men and women over a wide age range) were excluded as the creatinine reference value could not be determined.

Daily iodine intake was estimated from UIC accounting for urine volume, or 24-hour urine samples (UIE) according to WHO (2024). For those studies reporting UIC and creatinine, we estimated UIE by multiplying median UIC:UCC ratio with population-specific reference values for daily urinary creatinine excretion. Reference values for creatinine for men and women according to different age groups were retrieved from a Belgian population study by Kestelhoot et al. (1996). For pregnant women, we used age- and sex-specific reference ranges for non-pregnant women (Fischer et al., 2024). For children we used sex, age and anthropometry specific reference values (Remer et al., 2002). The daily iodine intake was estimated from UIE assuming that 92% of the consumed iodine is excreted in urine (WHO, 2024).

Median iodine intake values with 95% confidence intervals (CI) were compared between the national dietary surveys and the biomarker studies. This approach was chosen because most biomarker studies rely on single spot urine samples, which show substantial day-to-day variability. The 95% CI for the median had to be estimated from the interquartile range (IQR) or percentiles (P25 and P75) in eight of 12 studies that did not include a 95% CI. The method gives an approximate confidence interval for the median (estimated as median ± $1.58 \times IQR/\sqrt{n}$) based on McGill et al. (1978)

Table A-1 Eligibility criteria for primary studies of iodine intake in Norway based on urinary iodine.

Criterion	Inclusion	Exclusion
Study design	Cross-sectional, health survey, intervention study/RCT (pre-intervention results only), cohort study	
Target population	Norwegian general population age 1 to 80 years. Sub-groups included, e.g. pregnant	

Criterion	Inclusion	Exclusion
	and lactating women and those adhering to special diets (e.g. vegetarian) or seaweed consumers	
Outcome data	At least one spot urine sample (UIC) adjusted for creatinine, estimated UIE, measured UIE, or intake calculated from UIE. Fasting or morning urine included.	No reported creatinine adjustment of UIC, or UIC/UCC ratios for combined groups with differing creatine reference values (e.g. men and women over a wide age range)
Response rate	No restriction	
Laboratory analysis methods for UIC, creatine, UIE	No restriction	
Sample size	No restriction	
Publication years	2003 to 2025	
Data collection years	Data collection years relevant for the most recent national dietary survey (Norkost 4, Ungkost 3, Spedkost 3, Småbarnskost 3)	Studies in adults with data collected before Norkost 3 (2010-2011)
Language	No restriction	
Type of literature	Primary studies	Primary studies with overlapping results. Overview/review studies and reports screened for primary studies before exclusion.

Table A-2 List of screened studies

Author, year	Title	Journal	Year	DOI	Include (short name)/exclude	Exclusion reason
Aakre et al., 2026	Impact of habitual seaweed consumption on iodine nutrition and thyroid function: a non-randomized pre-post clinical study	European Journal of Nutrition, *65*(1), 27	2026	https://doi.org/10.1007/s00394-025-03813-8	Included (Seaweed_Berg_Oslo)	
Johnsen et al., 2025	Inadequate iodine status among women of childbearing age in Northern Norway: a cross-sectional study	*Food & Nutrition Research*, *69*, 10802	2025	https://doi.org/10.29219/fnr.v69.10802	Included (MISA2_FF3_North)	
Abel et al., 2024a	Iodine status and determinants in adults in Norway – results from a population-based health examination survey (The HUNT Study)	Food & Nutrition Research, 68, 9761	2024	https://doi.org/10.29219/fnr.v68.9761	Included (HUNT4_NTr)	
Abel et al., 2024b	Iodine status in two-year-old children and women of childbearing age – Results from a national monitoring study in Norway in 2022–23	Norsk Tidsskrift for Ernæring, 22(5)	2024	https://doi.org/10.18261/ntfe.22.5.89	Included, abstract (Monitoring_national)	
Groufh-Jacobsen et al., 2024	Micronutrient intake and status in young vegans, lacto-ovo-vegetarians, pescatarians, flexitarians, and omnivores	European Journal of Nutrition, 63(7), 2725–2741	2024	https://doi.org/10.1007/s00394-024-03453-4	Excluded	No creatinine adjustment
Aarsland et al., 2023	Iodine Nutrition in Children ≤2 years of Age in Norway	The Journal of Nutrition, 153(11), 3237–3246	2023	https://doi.org/10.1016/j.tjnut.2023.09.013	Excluded	No creatinine adjustment
Henjum et al., 2023	Thyroid function and urinary concentrations of iodine, selenium, and arsenic in vegans, lacto-ovo vegetarians and pescatarians	European Journal of Nutrition, 62(8), 3329–3338	2023	https://doi.org/10.1007/s00394-023-03218-5	Included (PlantDiets_Oslo)	
Rosendahl-Riise et al., 2023	Comparison of a digital iodine-specific dietary screener with 24-hour recall and urinary iodine concentration	Journal of Nutritional Science, 12, e90	2023	https://doi.org/10.1017/jns.2023.74	Excluded	No creatinine adjustment
Groufh-Jacobsen et al., 2023	National monitoring of iodine, sodium, and vitamin D status in toddlers and women of childbearing age - results and lessons learned from a pilot study in Norway	Food & Nutrition Research, *67*, 9088	2023	https://doi.org/10.29219/fnr.v67.9088	Excluded	Pilot study, main study included (Abel et al., 2024b)

Author, year	Title	Journal	Year	DOI	Include (short name)/exclude	Exclusion reason
Aakre et al., 2021	Iodine status during pregnancy and at 6 weeks, 6, 12 and 18 months post-partum	Maternal & Child Nutrition, 17(1), e13050	2021	https://doi.org/10.1111/mcn.13050	Excluded	No creatinine adjustment
Bakken et al., 2021	Adequate Urinary Iodine Concentration among Infants in the Inland Area of Norway	Nutrients, 13(6), 1826	2021	https://doi.org/10.3390/nu13061826	Excluded	No creatinine adjustment
Næss et al., 2021	Iodine Nutrition and Iodine Supplement Initiation in Association with Thyroid Function in Mildly-to-Moderately Iodine-Deficient Pregnant and Postpartum Women	The Journal of Nutrition, 151(10), 3187–3196	2021	https://doi.org/10.1093/jn/nxab224	Included (Mommys Food_Bergen)	
Øyen et al., 2021	Lean-seafood intake increases urinary iodine concentrations and plasma selenium levels: a randomized controlled trial with crossover design	European Journal of Nutrition, *60*(3), 1679–1689	2021	https://doi.org/10.1007/s00394-020-02366-2	Excluded	No creatinine adjustment
Groufh-Jacobsen et al., 2020a	Mild to Moderate Iodine Deficiency and Inadequate Iodine Intake in Lactating Women in the Inland Area of Norway	Nutrients, 12(3), 630	2020	https://doi.org/10.3390/nu12030630	Excluded	No creatinine adjustment
Madar et al., 2020	Iodine Intake in Norwegian Women and Men: The Population-Based Tromsø Study 2015-2016	Nutrients, 12(11), 3246	2020	https://doi.org/10.3390/nu12113246	Included (Tromsø7)	
Groufh-Jacobsen et al., 2020b	Vegans, Vegetarians and Pescatarians Are at Risk of Iodine Deficiency in Norway	Nutrients, 12(11), 3555	2020	https://doi.org/10.3390/nu12113555	Excluded	No creatinine adjustment
Nerhus et al., 2019	Iodine status in Norwegian preschool children and associations with dietary iodine sources: the FINS-KIDS study	Journal of Nutrition, *58*(6), 2219–2227	2019	https://doi.org/10.1007/s00394-018-1768-0	Included (FINS_KIDS_Bergen)	
Henjum et al., 2018a	Suboptimal Iodine Status and Low Iodine Knowledge in Young Norwegian Women	Nutrients, 10(7), 941	2018	https://doi.org/10.3390/nu10070941	Excluded	No creatinine adjustment
Henjum et al., 2018b	Suboptimal Iodine Status among Pregnant Women in the Oslo Area, Norway	Nutrients, 10(3), 280	2018	https://doi.org/10.3390/nu10030280	Included (Preg_Oslo)	
Madar et al., 2018	Iodine Status among Somali Immigrants in Norway	Nutrients, 10(3), 305	2018	https://doi.org/10.3390/nu10030305	Included (Somali_Oslo)	

Author, year	Title	Journal	Year	DOI	Include (short name)/exclude	Exclusion reason
Brantsæter et al., 2018	Inadequate Iodine Intake in Population Groups Defined by Age, Life Stage and Vegetarian Dietary Practice in a Norwegian Convenience Sample	Nutrients, 10(2), 230	2018	https://doi.org/10.3390/nu10020230	Included (Lifestage_Oslo)	
Aakre et al., 2018	Sufficient iodine status among Norwegian toddlers 18 months of age – cross-sectional data from the Little in Norway study	Food & Nutrition Research, 62, 1443	2018	https://doi.org/10.29219/fnr.v62.1443	Excluded	No creatinine adjustment
Dahl et al., 2018	Iodine Deficiency in a Study Population of Norwegian Pregnant Women—Results from the Little in Norway Study (LiN)	Nutrients, 10(4), 513	2018	https://doi.org/10.3390/nu10040513	Included (LiN_national)	
Abel et al., 2018	Iodine Intake is Associated with Thyroid Function in Mild to Moderately Iodine Deficient Pregnant Women	Thyroid, 28(10), 1359–1371	2018	https://doi.org/10.1089/thy.2018.0305	Excluded	Data in adults collected before Norkost3 (2010)
Handeland et al., 2018	The effects of fatty fish intake on adolescents' nutritional status and associations with attention performance: results from the FINS-TEENS randomized controlled trial	Nutrition Journal, *17*(1), 30	2018	https://doi.org/10.1186/s12937-018-0328-z	Excluded	No creatinine adjustment
Thomassen et al., 2017	Iodine Status and Growth In 0–2-Year-Old Infants With Cow's Milk Protein Allergy	Journal of Pediatric Gastroenterology and Nutrition, *64*(5), 806–811	2017	https://doi.org/10.1097/MPG.0000000000001434	Excluded	No creatinine adjustment
Molin et al., 2017	Arsenic in seafood is associated with increased thyroid-stimulating hormone (TSH) in healthy volunteers – A randomized controlled trial	Journal of Trace Elements in Medicine and Biology, 44, 1–7	2017	https://doi.org/10.1016/j.jtemb.2017.05.004	Excluded	Data in adults collected before Norkost3 (2010)
Berg et al., 2017	Thyroid homeostasis in mother–child pairs in relation to maternal iodine status: the MISA study	European Journal of Clinical Nutrition, *71*(8), 1002–1007	2017	https://doi.org/10.1038/ejcn.2017.83	Excluded	Data in adults collected before Norkost3 (2010). MISA3 included (Johnsen et al., 2025)

Author, year	Title	Journal	Year	DOI	Include (short name)/exclude	Exclusion reason
Abel et al., 2017	Maternal Iodine Intake and Offspring Attention-Deficit/Hyperactivity Disorder: Results from a Large Prospective Cohort Study	Nutrients, 9(11), 1239	2017	https://doi.org/10.3390/nu9111239	Excluded	Data in adults collected before Norkost3 (2010)
Henjum et al., 2017	Suboptimal Iodine Concentration in Breastmilk and Inadequate Iodine Intake among Lactating Women in Norway	Nutrients, 9(7), 643	2017	https://doi.org/10.3390/nu9070643	Excluded	No creatinine adjustment
Dahl et al., 2003	Iodine intake and status in two groups of Norwegians	Scandinavian Journal of Nutrition, 47(4), 170–178	2003	https://doi.org/10.1080/11026480310018131	Excluded	Data in adults collected before Norkost3 (2010)

Table A-3 Included studies of iodine intake based on urinary iodine mapped to national dietary surveys.

National dietary survey	Age group, years	Included biomarker studies (n=12)
Norkost 4	18-80	General pop men (n=3): HUNT4_NTr(age 25-79), Tromsø7(age 40-69), Somali_Oslo(age 20-73) General pop women (n=4): HUNT4_NTr(age 25-79), Tromsø 7(age 40-69), Somali_Oslo(age 20-73), MISA2_FF3 – non pregnant (age 19-36) Pregnant women (n=5): MISA2_FF3-pregnant (age 20-46), Mommys Food, Preg_Oslo, Lifestage_Oslo, LiN_national) Other vulnerable groups (n=2): Plant_diets Oslo (n=1) Seaweed_Berg_Oslo (n=1)
Ungkost 3	13	Adolescents: Males/females combined: Lifestage_Oslo (age 10-17, mean 13)
	9	Lifestage_Oslo (age 3-9, mean 6)
	4	Male/female separate: FINS_KIDS_Bergen (age 4-6 yrs, mean 5)
Småbarnskost 3	2	National monitoring program (313 children age 2, usual intake estimated from 76 UIC/UIE replicates)
Spedkost 3	1 -weaned	None identified with UIC adjusted creatinine
	1-breastfed	None identified with UIC adjusted creatinine

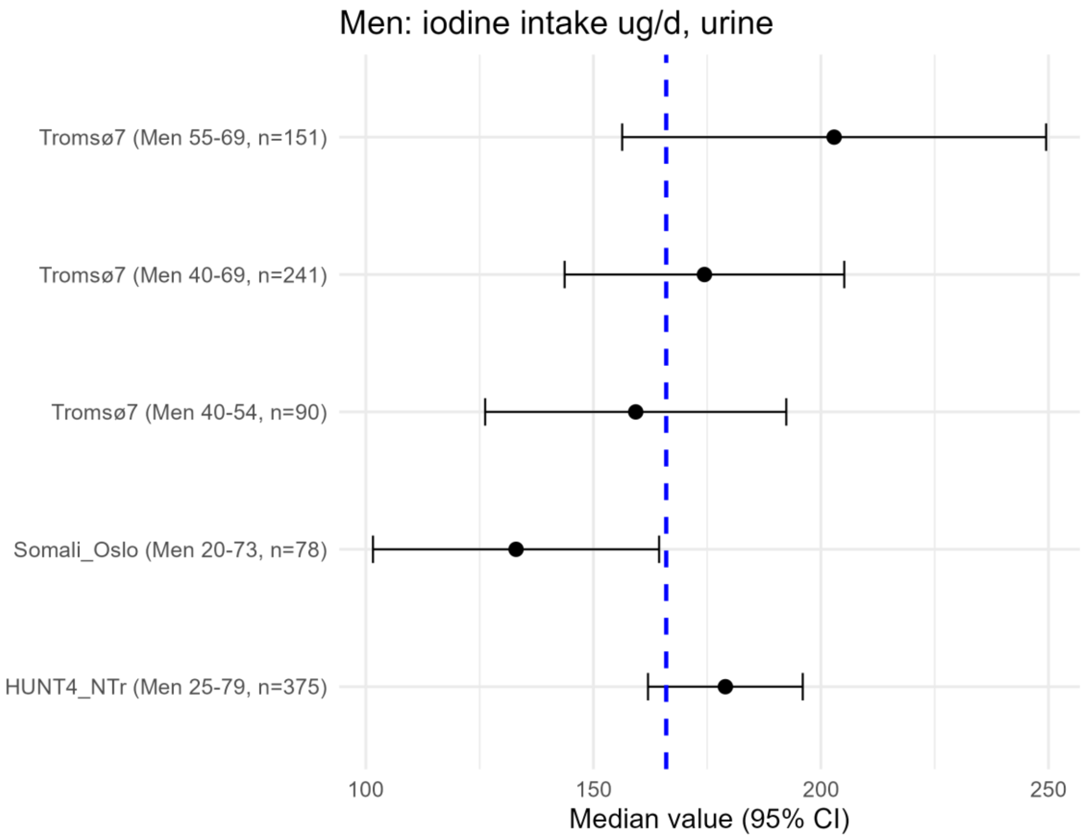

Figure A-1 Comparison in men of median (95% CI) urinary iodine intakes with national dietary survey Norkost 4 (blue reference line, median 166 µg/day).

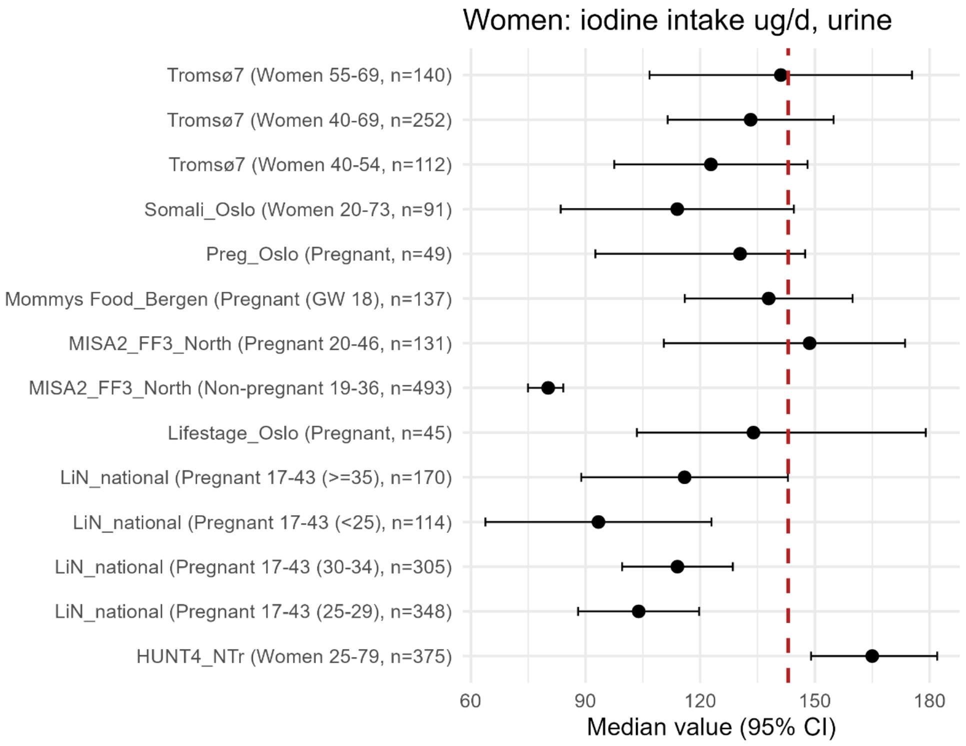

Figure A-2 Comparison in women of median (95% CI) urinary iodine intakes with national dietary survey Norkost 4 (red reference line, median 143 µg/day).

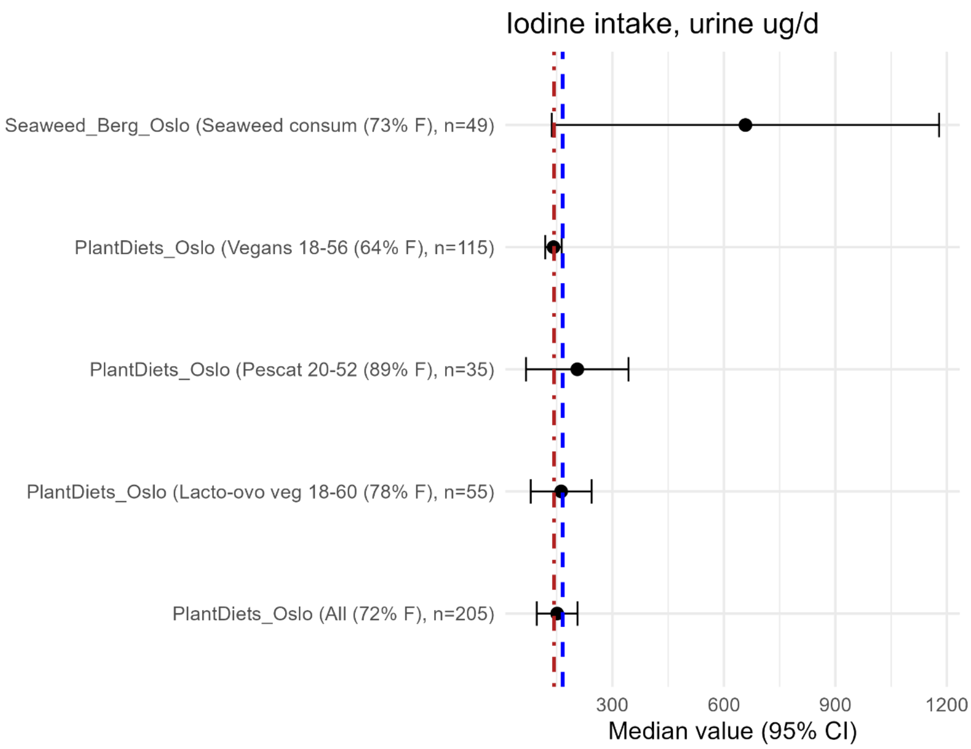

Figure A-3 Comparison in men and women (F) combined of median (95% CI) urinary iodine intakes in selected groups (vegetarian, or seaweed users) compared with national dietary survey Norkost 4 (All men: blue reference line 166. All women: red reference line 143).

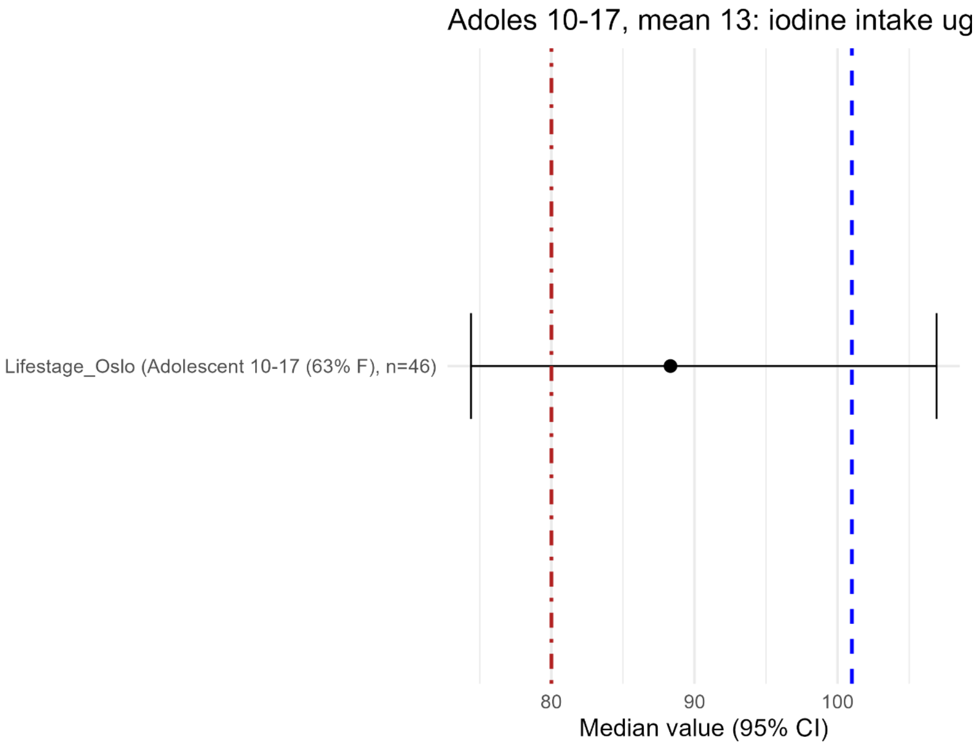

Figure A-4 Comparison in adolescents age 10 to 17 (mean 13) years of median (95% CI) urinary iodine intake with national dietary survey Ungkost 3 in 13-year olds (blue reference line: boys 101, red reference line: girls 80. Median µg/day).

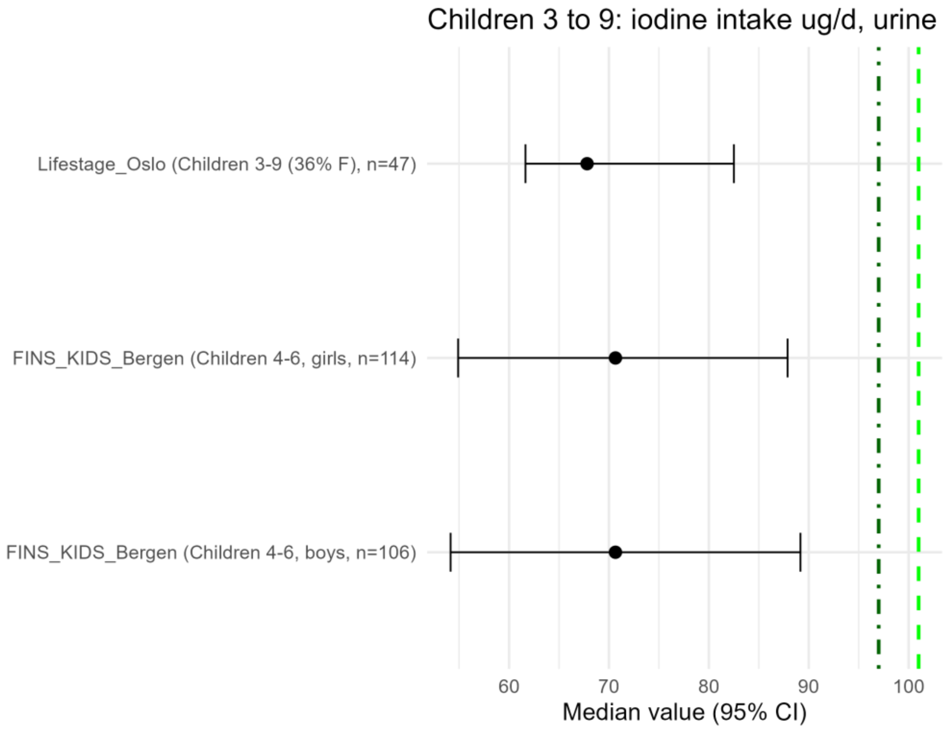

Figure A5 Comparison in children age 3 to 9 years of median (95% CI) urinary iodine intake with national dietary survey Ungkost (light green reference line: age 4 yrs boys/girls 101, dark green reference line: age 9 yrs boys/girls, 97. Median µg/day).

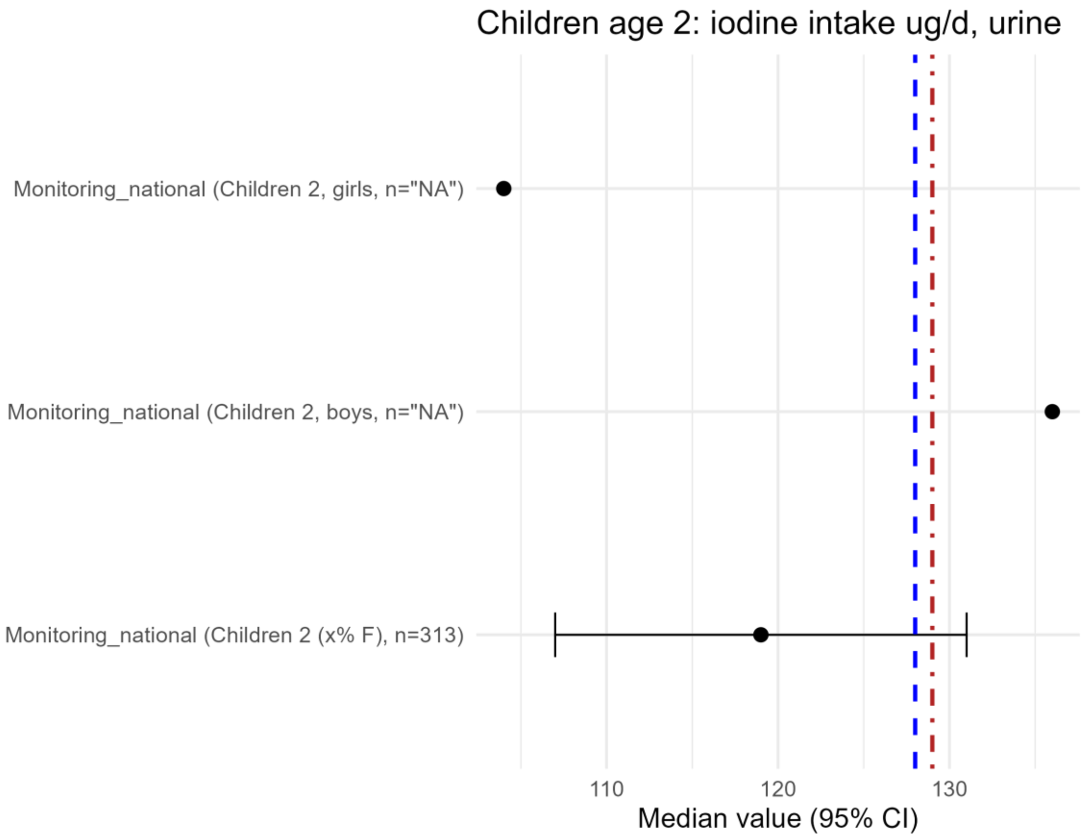

Figure A-5 Comparison in children age 2 of median (95% CI) urinary iodine intake with national dietary survey Småbarnskost 3 (blue reference line: boys 128, red reference line: girls 129. Median µg/day).

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