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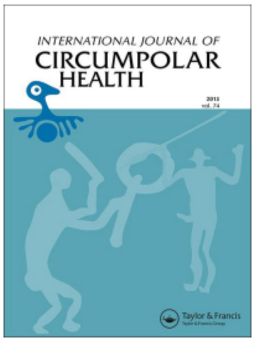
Published in:
International Journal of Circumpolar Health

DOI (link to publication from Publisher):
10.1080/22423982.2023.2233145

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Johannesen, H. L., Andersen, S., Weihe, P., Petersen, M. S., Strøm, M., & Veyhe, A. S. (2023). The iodine content of Faroese food items to support iodine nutrition in the North Atlantic. *International Journal of Circumpolar Health*, *82*, Article 2233145. https://doi.org/10.1080/22423982.2023.2233145



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International Journal of Circumpolar Health

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/zich20

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To cite this article: Herborg Líggjasardóttir Johannesen, Stig Andersen, Pál Weihe, Maria Skaalum Petersen, Marin Strøm & Anna Sofía Veyhe (2023) The iodine content of Faroese food items to support iodine nutrition in the North Atlantic, International Journal of Circumpolar Health, 82:1, 2233145, DOI: 10.1080/22423982.2023.2233145

To link to this article: https://doi.org/10.1080/22423982.2023.2233145

INTERNATIONAL JOURNAL OF CIRCUMPOLAR HEALTH
2023, VOL. 82, 2233145
https://doi.org/10.1080/22423982.2023.2233145

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RESEARCH ARTICLE

The iodine content of Faroese food items to support iodine nutrition in the North Atlantic

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ABSTRACT

Iodine is essential for human health, and dietary iodine sources are critical. Living isolated on islands in the North Atlantic Ocean fostered unique dietary traditions in the Faroe Islands. The dietary peculiarities led us to collect and measure the iodine content of local foods and beverages and calculate daily iodine intakes based on four Faroese dietary scenarios. Marine foods and birds had iodine contents from 300 µg/kg and up, markedly higher than dairy, grains, terrestrial, vegetables, and liquid foods ($p<0.001$). Vegetables and beverages contained negligible iodine. Wind-dried fermented lamb meat iodine content varied by 100% depending on whether it was herded on an island with beaches (105 µg/kg) or with cliffs (53 µg/kg) facing the ocean. The daily iodine intake varied from around 50 µg to just over 200 µg with diets rich in fish and whales. In conclusion, the traditional diet has been a critical source of iodine on the Faroe Islands. The Faroese may be iodine replete with traditional diets but face the risk of iodine deficiency with dietary transition towards a more western diet. Locally produced Faroese foods are therefore relevant to promote health, and may additionally support food security, local involvement and knowledge, and long-term sustainability.

ARTICLE HISTORY
Received 23 January 2023
Revised 22 June 2023
Accepted 30 June 2023

KEYWORDS
Iodine; traditional food; Faroe Island; source of iodine; nutrition; food security

Introduction

Iodine is an element that is essential for human growth and development [1] and plays a vital role in the occurrence of thyroid disorders [2]. Human iodine status is dependent on dietary sources, and the iodine content of food items determines the individual subject's iodine intake [3–5]. Iodine-rich foods include marine mammals and fish, and milk and other dairy products [6,7]. Additionally, tap water may contribute to the iodine intake in some areas [8].

The Faroe Islands are a group of 18 islands in the North Atlantic Ocean, with no single spot being more than 5 kilometres from the sea [9]. The proximity to the sea may influence local foods' iodine content, and we hypothesise that the traditional Faroese foods are iodine rich. Local food items are those produced and consumed in the Faroe Islands, including food items that are sourced from both land and sea, and are a part of the traditional, local Faroese diet. A growing local movement is the initiative to explore the possibilities for the Faroese to be self-supplied. Thus, the word of the year in 2022 in the Faroe Islands was "stuttflutt", meaning "locally produced". Local productions are ample, and the Faroese cuisine includes local, traditional foods such as fermented and wind-dried lamb meat, seabirds, fish, and Faroese milk [10]. Pilot whale hunting, by driving and communal sharing, is an old tradition that was cherished for centuries and still is [11]. However, recommendations are to limit the intake of both whale meat and blubber or even not to eat it at all due to the content of environmental pollutants [12,13].

Food tables for iodine are lacking in the Faroe Islands, and foreign records such as the Danish database "Frida" [14] have been used for estimating intake from Faroese foods. One study based on diet interviews estimated mean iodine intake in the Faroe Islands at 244 µg/day [15]. Faroese teenagers were iodine replete [16], while urine iodine concentration was 86 µg/L in a cross-sectional study of Faroese women raising a concern for iodine

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/22423982.2023.2233145.

deficiency even in areas surrounded by the sea [17]. Thus, uncertainties have emerged about the iodine intake in the Faroese population and, particularly, the iodine content in Faroese food. These uncertainties led us to measure the iodine content in local food products. Based on the measured iodine content, we calculated the iodine intake from four Faroese dietary scenarios.

Methods

Foods and beverage samples were collected or purchased in local stores in November 2021. We kept food items frozen in iodine-free containers until analysis. We sampled two dummy tests and 89 Faroese food items: 34 dairy products, 15 marine-, 13 terrestrial-, 9 beverages-, 7 vegetables-, and 11 additional samples, as listed in Table 1. Dairy products included milk, yoghurt, cream, sour cream, cheese, and butter. Repeated sampling of milk and cream was performed to evaluate between-day fluctuations. Marine samples included local food items sold in stores: cod, halibut, and salmon. Local hunters supplied meat and blubber from pilot whale, fermented lamb, seabirds (common guillemot and puffin), and hare. We sampled lamb from farmers on three islands to assess the impact of geography. The islands were Hestur, Streymoy (Leynar), and Eysturoy (Glyvrar). We also measured iodine in samples from the lamb's organs: heart, kidney, liver, blood, tallow, and rolled seasoned meat (a sausage made of rolled mutton). We sampled wheat and rye bread from a local bakery, made home-baked rye bread (by H.L.J.), pizza, and traditional dry biscuit. We included five different types of locally purchased salt. The selection of Faroese vegetables, herbs and fruits is sparse, and only a few locally grown products are available. We sampled potatoes, carrots, brassica species, rhubarb jam, and parsley. Finally, we sampled beverages comprising three beers, one cider and three soft drinks, all of which were produced locally.

Samples were blinded by random order labelling before they were shipped for analysis to keep the laboratory blinded to the food items during sample handling, iodine measurement, and reporting of test results. Samples included two dummy samples: one of water with negligible iodine contents subsequently spiked with iodine as described elsewhere [18], and one with Icelandic lamb, with median iodine content of 32–52 µg/kg (0–127 µg/kg) [19].

Definition of food groups and calculation of iodine intake

A recent report described food classification for the UK biobank and recommended fifteen main food categories (13 food and two beverage categories) [20]. To support our calculation of the iodine intake based on a daily dietary intake from the included foods in this study we chose to categorise the foods into six groups of local foods and one with beverages. These were logical to the food items available: marine-, seabirds, meat, grains, dairy products, offal, vegetables-, and salt, and beverages. We included a group of other food items ("other") when there was no or minimal commercial Faroese production of the food item. The individual samples' iodine content is shown in supplementary table S1.

We listed four typical Faroese dietary scenarios for the calculation of the iodine intakes of an individual using the local products. The meals were composed based on Faroese dietary reports for adults [10,15,21,22]. We based the calculation on the consumption of 600–800 grams of foods in three main meals and a daily fluid intake of 1600 ml, as listed in Table 2. The breakfast comprised of bread, butter, cheese, rhubarb jam, milk, and water for all four days. A biscuit with butter and cheese was included for a snack. Lunch comprised of bread, butter, kohlrabi pickled, and water all four days, and toppings of liver pate, sausage roll, wind-dried fermented sheep for two days, and fishcakes and salmon for two days. Dinners were either a meat meal with fermented sheep, kohlrabi raw and potato; cod twice with different milk consumptions, or whale meat and blubber with increasing the milk intake. These Faroese dietary scenarios can hence be summarised as follows: breakfast followed by four different food patterns for the day with (1) Meat dinner and Meat lunch; (2) Fish dinner and Meat lunch; (3) Fish dinner and Fish lunch; or (4) Whale dinner and Fish lunch. Details are listed in Table 2, and the iodine content of Faroese foods was multiplied by the intake of each food item and beverage. The sum of iodine contents of the food intakes added up to the calculated total daily iodine intake.

Assay procedures

The iodine concentration in food items was determined by the Sandell-Kolthoff reaction modified after Wilson and van Zyl [23]. The principle is detecting the catalytic role of iodine in reducing ceric ammonium sulphate in the presence of arsenous acid after pre-treatment with alkaline ashing. The pre-treatment protocol was modified for conducting the measurement in solid items. The iodine laboratory at Aalborg University Hospital (Aalborg, Denmark) has vast experience with these procedures [24,25], and is included in the Ensuring the Quality of Urinary Iodine Procedures (EQUIP) program (Department of Health and Human Services, CDC, USA). We use a rigorous and validated protocol for measuring the iodine content of solid and liquid items [6]. The measurement unit for iodine content in solid products was micrograms per kilogram (µg/kg) and micrograms per litre (µg/L) in liquids. Measuring iodine was complicated for certain solid samples with very high iodine concentrations. In these samples, we chose to provide the valid result, which was "high iodine concentration" reported as >320 µg/kg. The coefficient of variation for liquids at our laboratory is 9.2% (interval 1–4 µg/L, $n = 8$); 8.7% (interval 5–9 µg/L, $n = 4$); 4.2% (interval 10–15 µg/L, $n = 4$); 1.5% (interval 15–50 µg/L, $n = 5$); 1.5% at higher levels after dilution of samples [18]. The analytical coefficient of variation was determined for solid items with the Faroese food items: 20.3% (interval 10–45 µg/kg, $n = 8$); 8.7% (interval 50–85 µg/kg, $n = 5$); 7.5% (interval 100–400 µg/kg, $n = 3$). For solid food items we managed measurements up to 400 µg/kg, but for most samples with high iodine contents we the highest values were reported validly to be above 320 µg/kg.

The iodine concentration in the dummy samples were according to expected values. The water sample had low iodine content identical to a previous measurement [18], and the solid item (Icelandic lamb meat) had an iodine content as reported in Icelandic nutrient tables.

Statistics

The statistical analyses were performed in the R environment for statistical computing (version 4.2.1) [26,27]. Data are presented with numbers, percentages, mean, minimum, maximum, median, and interquartile range. We tested data for normality by visually inspection of QQ-plots. The model assumptions were that the observations from different food groups were independent and the individual observation within each group was independent. Differences between food groups were calculated using the One-way ANOVA. A p-value <0·05 indicated a statistically significant difference.

Results

Marine food items from the North Atlantic Ocean had high iodine contents of around 300 µg/kg or higher. Beverages, including tap water, had consistently low iodine contents of <2 µg/L. Figure 1 illustrates the differences in iodine content between food groups.

Table 1 lists the iodine contents of the collected Faroese food items. Marine foods had markedly higher iodine contents than other foods ($p < 0.001$), and the iodine content was distinctly higher than terrestrial foods ($p < 0.001$). Seabirds had iodine contents mirroring that measured in fish. Store-bought bread and pizza had iodine contents above 100 µg/kg, while other grains were lower in iodine content (Table 1, supplementary table S1).

The median iodine concentration of sixteen samples of four kinds of milk collected over one month was 67 µg/L [IQR 12], the lowest at 39 µg/L and the highest at 89 µg/L. The daily variation was limited with no time trend ($p > 0.1$). The iodine content was similar between the different types of milk products ($p = 0.1$). Other dairy products ranged from 42 to 189 µg/L.

As for terrestrial foods, lamb had an average iodine content of 56 µg/kg, while it was only 12 µg/kg in vegetables. The five local salt products varied from 9–16 µg/kg, with "Gestus Cornwall England Salt" being an exception having an iodine content of 72 µg/kg. Finally, all nine beverages, brewed or produced based on the local water, had negligible iodine contents (<2 µg/L).

Lamb meat iodine content varied by 100% depending on whether it was herded on an island with beaches (Figure 2) or with cliffs facing the ocean (Table 1). The four Faroese diets with varying consumption of meat and fish for main dishes, adding side dishes and drinks, are listed in Table 2. The results indicate a total daily iodine intake that spans from 50 µg/day for meals based on terrestrial meat to above 200 µg/day when meals were based on marine dishes (Table 2).

Discussion

These are the first Faroese data on iodine content of Faroese food items. Our study showed that Faroese marine foods were iodine rich, followed by grain and dairy products, while terrestrial food items had low iodine contents. In addition, local water-based products and vegetables had negligible iodine content. Our findings corroborate and details previous reports that marine foods generally have a higher iodine content than terrestrial food items [6,14]. The present data are interesting as maintaining life on the small, remote islands in the North Atlantic Ocean requires adaptation to the local environment. Such adaptation is reflected in dietary peculiarities, including fermented and wind-dried lamb meat and pilot whale, hunting and driving, contributing to both local culture and to the iodine intake.

Seabirds' high iodine content is interesting although not surprising, as they often feed on small fish. It illustrates that living on the Faroe Islands requires an adaptation to local opportunities and that these are related

Table 1. Iodine-content food items produced in the Faroe Islands.

Food groups		Food items	Samples	Mean µg/kg or *µg/L*	Min	Max
Dairy products	Milk and yoghurt	Milk[a]	16	*67*	*39*	*89*
		Sour cream and yoghurt[b]	6	*89*	*42*	*189*
		Cream[c]	7	*49*	*39*	*64*
	Cheese	Butter	3	*28*	*24*	*35*
		Cheese[d]	2	*70*		
Marine products	Fish products	Cod[e]	2	>320		
		Salmon	3	>320		403
		Halibut	1	>320		
		Fish balls (homemade)[f]	1	>320		
		Fish balls (commercial)	1	84		
		Fish sausage	1	48		
	Whale	Whale meat[g]	1	>320		
		Whale blubber[h]	1	>320		
	Seaweed	Seaweed	2	>320		
	Sea birds	Common guillemont[i] (fat)	1	>320		
		Puffin (meat)	1	244		
Terrestrial products	Meat	Sausage roll (lamb)	2	25		
		Fermented meat (lamb)	3	76	53	105
		Hare	1	20		
	Offal	Heart (lamb)	1	19		
		Kidney (lamb)	1	64		
		Liver (lamb)[j]	2	39		
		Blood (lamb)	1	125		
		Tallow[e]	2	21		
Grains		Bread[k]	2	178		
		Rye bread (home-baked)	1	39		
		Non-sweet biscuit	1	27		
		Pizza	1	128		
Vegetables	Vegetables	Kohlrabi root (raw)	1	12		
		Kohlrabi root (pickled)	1	8		
		Carrot (raw)	1	12		
	Potatoes	Potato (raw)	2	14		
		Potato (boiled)	1	23		
	Other	Parsley (domestic-grown)	1	209		
		Rhubarb jam	1	5		
Salt		Salt	5	24	9	72
Beverages		Beer	3	*1*		
		Sparkling water	3	*0*		
		Cider	1	*0*		
		Liquor	2	*0*		

[a]Includes four types of fat content: 0.1%; 0.5%; 1.5%; 3.5%. [b]Includes sour cream and plain & fruity yoghurt. [c]Fat content 38%. [d]One type of cheese. [e] Fresh and fermented. [f]Content is nearly 100% fresh fish. [g]Dried whale meat. [h]Salted whale blubber. [i]Uria aalge. [j]Paté and raw liver. [k]Commercially produced wheat and rye.

to the sea. Hence, the birds on the remote islands support life by using sea-based food substances, which contribute to the high iodine content of the birds. This finding may be a parallel to human nutrition in the same environment in the North Atlantic.

We previously reported that the frequency of fish meals was associated with urinary iodine concentration among Faroese [17]. People living in harsh coastal areas, an environment unfavourable to terrestrial food production, often rely on a diet dominated by marine food items. This is the case for people living on islands in the North Atlantic, such as the Faroes, Shetland, Orkney Islands, and Iceland. All face changes in dietary habits [21,22,28,29] with an influx of junk food, western-style foods, and restaurants. The fish intake decreased from 70 to 40 grams per day between 1982 and 2001 [22], and recent data illustrated an even lower fish consumption today, especially among younger generations [21].

Fishcakes and cold cuts are mixed products containing a fillet of fish, often haddock, milk powder, cornflour, onion, herbs, and water. Adding water, spices, onion, and cornflour to marine food items lowered the iodine content of the composite dietary component. However, fishcakes are popular and seem to support the iodine intake in this population, where a dietary transition has implied a decrease in fish intake over the past decades [21].

Seaweed is a growing industry in the Faroe Islands and an upcoming food gaining popularity. Therefore, we sampled seaweed from the local beach and found a high iodine concentration, in line with the previous reports of seaweed from the North Atlantic [30,31]. Seaweed has an excessive iodine content, but a study

Table 2. Estimated iodine intake based on four days of consumption of Faroese-produced food products, each column represents one day. The total intake of food ("g"), and the iodine intake, ("microg").

		Iodine content	Meat dinner Meat lunch		Fish dinner Meat lunch		Fish dinner Fish lunch		Whale dinner Fish lunch	
	Meal	µg/kg	g	µg	g	µg	g	µg	g	µg
Foods	Cod	307	-		150	46.1	150	46.1	-	
	Salmon	400[a]	-		-		25	10.0	25	10.0
	Fishcake	84	-		-		20	1.7	20	1.7
	Whale meat	400[a]	-		-		-		175	70.0
	Whale blubber	400[a]	-		-		-		50	20.0
	Bread	178[b]	145	25.8	145	25.8	145	25.8	145	25.8
	Non-sweet biscuit	27	25	0.7	25	0.7	25	0.7	25	0.7
	Butter	28	35	1.0	35	1.0	35	1.0	35	1.0
	Cheese	70	45	3.2	45	3.2	45	3.2	45	3.2
	Liver pate	47	20	0.9	20	0.9	-		-	
	Sausage roll	35	13	0.5	13	0.5	13	0.5	-	
	Wind dried sheep (cold cut)	79	20	1.6	20	1.6	20	1.6	20	1.6
	Fermented sheep (dinner)	50	150	7.5	-		-		-	
	Salt	24	8	0.2	8	0.2	8	0.2	8	0.2
	Kohlrabi (raw)	12	20	0.2	20	0.2	20	0.2	20	0.2
	Kohlrabi (pickled)	8	20	0.2	20	0.2	20	0.2	20	0.2
	Carrot	12	20	0.2	20	0.2	20	0.2	20	0.2
	Potato boiled	23	180	4.1	180	4.1	180	4.1	180	4.1
	Rhubarb jam	5	20	0.1	20	0.1	20	0.1	20	0.1
	Total intake		**721**	**46.2**	**721**	**84.8**	**746**	**95.6**	**808**	**139.0**
	Drinks	µg/L	mL	µg	mL	µg	mL	µg	mL	µg
Drinks	Tap water	0	1350	0.0	1350	0.0	1000	0.0	400	0.0
	Sparkling water	0	-		-		200	0.0	-	
	Milk	67	50	3.4	50	3.4	400	26.8	1000	67.0
	Beer	0	200	0.0	200	0.0	-		200	0.0
	Total drink intake		**1600**	**3.4**	**1600**	**3.4**	**1600**	**26.8**	**1600**	**67.0**
Estimated iodine intake	Iodine from foods:			46.2		84.8		95.6		139.0
	Iodine from drinks			3.4		3.4		26.8		67.0
	Total iodine			**49.6**		**88.2**		**122.4**		**206.0**

[a]Iodine content in the food product was >320 µg/kg (see Table 1) and therefore an estimated iodine concentration is provided. [b]Bread includes rye- and wheat bread and the iodine content is average one rye bread and one wheat bread sample (see Supplementary Table S1).

showed no short-term adverse effects on thyroid function [32], and seaweed intake may support long-term iodine nutrition when the intake of other marine foods decreases.

Our results indicate that not only marine animals, but also other Faroese foods contribute to the general iodine status, including dairy products and grain. The Faroese have a habit of eating relatively high amounts of bread [21], and our data showed a relatively high median iodine content in grains of 106 µg/kg [IQR 139]. Furthermore, salt contributes to the iodine intake. There is no legislation on salt iodisation in the Faroe Islands, but most salt is imported from Denmark, where iodisation of table and industrial salt is mandatory [33]. Our findings conform to the use of iodised industrial salt for commercial bread production, and the central bakeries confirm the use of iodine-fortified salt. Both iodised and non-iodised salt are available in the stores, albeit all the salt products in our study contained iodine. Hence, our findings corroborate that iodised salt was available in stores to be used for cooking, though the use of iodised salt in our study may have led to a slight overestimation of iodine intake.

Locally produced dairy products had a mean iodine concentration of 67 µg/L with no apparent time trend. Herds are largely kept indoors all year, and therefore we would not expect a seasonal variation in iodine content of milk. Our findings were lower than those from Norway, reporting a seasonal variation with the higher median of 232 µg/L in winter [7], and iodine fortification of animal fodder since the 1950s [34]. There is only one dairy plant in the Faroe Islands, which receives milk from multiple farms. Thus, dairy products on the market are always pooled, and we do not have data on the individual milk farms. However, our findings show that the iodine content in Faroese milk was 67 µg/kg, lower than the 100 µg/kg [14] in Denmark and 160 µg/kg in Norway [35]. This finding suggests an evaluation of the need for iodine fortification of the fodder on Faroese farms.

The Faroese terrestrial diet is mainly lamb. We found that iodine in lamb meat varied widely, comparable to findings from Iceland [19]. We add that this is due to sheep in "Streymoy" having access to the sea and eating seaweed (Figure 2), unlike lamb from "Hestur", a rocky island with steep cliffs and no beaches. This illustrates an importance of proximity to the ocean.

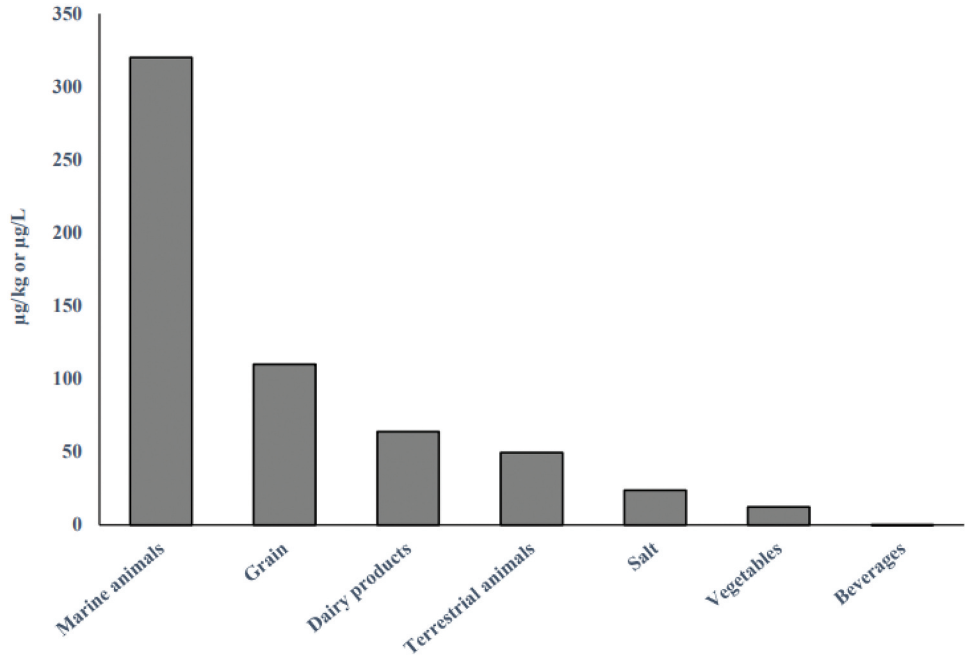

Figure 1. Mean iodine contents of groups of 89 Faroese foods to portray the relative importance of items for iodine intake among people living in isolated islands in the North Atlantic Ocean.

Figure 2. Picture a sheep in the Faroe Islands searching for food on the coast and eating seaweed. It was printed with permission from copyright holder Bjarki G. Dalsgarð.

Tap water iodine is essential for iodine intake in some countries [36,37], but our results show that drinking water does not contribute to iodine intake in the Faroe Islands [17]. Similarly, beverages produced locally all had negligible iodine content and did not contribute to iodine nutrition.

Overall, data on Faroese food intake is sparse, but the major food groups are dairy products, grains, potatoes, meats, vegetables, and fish [21]. Based on our results, a healthy iodine intake relies on daily intake of marine, grain, and dairy products, while the contribution is limited when considering vegetables and beverages other than milk. We used the consumption and iodine content of Faroese foods to calculate a total daily iodine intake. Interestingly, it is possible to meet the recommended iodine intake based on only locally based Faroese foods. Our calculated iodine intake of a local Faroese diet showed that a diet combining terrestrial foods and a low intake of dairy products causes moderate iodine deficiency with an estimated intake of just under 50 µg/day. This is improved by swapping terrestrial with marine foods or adding dairy products and bread to the diet. The combination of seafood, bread and dairy foods is estimated to cause an intake slightly above the recommended range. Hence, Faroese may be iodine replete from local foods, but there is a risk of iodine deficiency when turning away from local marine foods.

The Faroese strive for self-supply, and local food production may support sustainability with limited transport and improve regional knowledge and involvement. Additionally, it may promote food security while supporting iodine intake. These possibilities are made explicit by the remoteness of the Faroe Islands, which highlights the opportunities for others to follow.

It is a strength that the study reports the iodine content of most Faroese foods available and hence portrays the local diet of these islands in the North Atlantic Ocean. More samples could be added to strengthen the validity of our results, but the variation between samples included was limited. Hence, the results provide a valid estimate of the iodine contents. We relied on previous dietary surveys and food frequency questionnaires to determine typical serving sizes for the Faroese population. It is important to note that while the literature on food intake is helpful for estimating dietary intake, it does have limitations and uncertainties. Also, some uncertainty remains on the iodine content of foods with very high iodine content. Still, we demonstrate that Faroese foods may provide both deficient and high iodine intakes depending on the use of a traditional diet.

We could not estimate seasonal variation, which has been reported from other areas with different dietary habits. Thus, this could be an interesting path to pursue in a future study.

Conclusion

The study reported iodine content in food items from the Faroe Island, and calculated iodine intake from traditional Faroe fare. The traditional Faroese diet could provide sufficient iodine since it contains marine foods, rich in iodine. Hence, conscientious food choices may enable the Faroese to be iodine replete without supplementation. Raising awareness may nudge the population towards this ambition, but this requires health promotion initiatives, legislation, and enforcement to promote self-supply. The ongoing dietary changes emphasise the need for such initiatives to improve professional and public knowledge of the possibilities for sustainable and healthy nutrition and the need for continuous monitoring of population iodine status. Presently, dietary changes emphasise a need to use iodised salt even with the local diet to ensure adequate intake. Future research should aim also to promote understanding the relationship between dietary habits and iodine status in the Faroe Islands.

Acknowledgments

Thanks to the hunters for donating samples from their animals. Thanks to Mjólkarvirkið Búnaðarmanna for assisting with the sampling of milk and cream. We acknowledge Eydfinn Lenvig for assessing the size of traditional Faroese dishes used for calculating iodine intakes from Faroese meals. Special thanks to photographer Bjarki G. Dalsgarð for permission to use the photo.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The Research Council at the Faroese National hospital (H.L.J., grant number 21/00010-36); North Denmark Region (S.A.); Betri Stuðul (H.L.J. grant number 1021).

Authorship

Principal investigators were H.L.J. and A.S.V. The author's contributions were the following: H.L.J., S.A., and A.S. V. sparked the idea, initiated the study, contributed to the design and implementation of the survey, ensured the writing and publishing processes, and contributed to the preparation of the manuscript. S.A. collaborates and assists with chemical analyses. H.L.J. and A.S.V. did the data analyses, and H.L.J., and S.A., were grant holders. All authors contributed to the interpretation of data and read and commented on the final draft.

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