

## Vitamin C in East-Greenland traditional nutrition: a reanalysis of the Høygaard nutritional data (1936-1937)

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### ABSTRACT

Greenlandic traditional nutrition was an almost exclusive meat dietary pattern. Høygaard et al. stayed in East-Greenland between August 1936 and August 1937. The four members of the expedition resided in Tasisaq and recorded nutritional intake by residing in families. However, data were analysed on a household level. The aim of the present study is to reanalyse the Høygaard et al. data according to modern scientific standards. In total 21 males and 14 females participated. Median (IQR) vitamin C intake was 79 (77) mg.day<sup>-1</sup> for males and 59 (56) mg.day<sup>-1</sup> for females. Consumption of meat and organs from seals gave 21 mg.d<sup>-1</sup> vitamin C, comparable to vitamin C from algae. Narwhal skin and eyes had a marginal contribution to the vitamin C consumption. The number of adults consuming algae during the research days was 67% for males and 71% for females, this was 24% and 21% for narwhal skin. The main conclusions of the present study are the important role of algae consumption in Greenlandic traditional dietary pattern to avoid scurvy, and that foods traditionally seen as important sources of vitamin C like eyes from seals and narwhal skin, played a minor role in meeting the vitamin C requirements.

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## Introduction

When excluding famine, scurvy is probably the nutritional deficiency disease that has caused the highest mortality in human history [1]. Scurvy, a disease due to a vitamin C intake of less than 10 mg.d<sup>-1</sup> for several months, was associated with abominable and debilitating suffering before death by heart failure occurred [1]. The symptoms of the disease were the consequences of the essential role of vitamin C or ascorbic acid in collagen synthesis. Without collagen, cartilaginous material disappears from joints, bones and scar tissue would begin to unknit [2]. Petechiae, i.e. small red or purple spots caused by bleeding into the skin, blackened gums, loose teeth, ulcers, and internal bleedings were the announcements of an impending and sometimes redeeming death.

Scurvy and a pre-scurvy stadium at the end of the winter were common in Western societies, due to a lack of fresh vegetable foods. The arctic environment, with very long winters and an almost total lack of fresh vegetable foods for the early explorers, was challenging to avoid scurvy. Those who left for the arctic, were seen as heroes, with a high probability of dying in unknown area, far from family and friends [1].

Inuit have inhabited the arctic for thousands of years living successfully of a dietary pattern based largely on sea mammals. In a dietary pattern composed mainly of animal food sources, the question arises with respect to the intake and sources of vitamin C in the Inuit traditional food system [1]. Scurvy was seldom observed in arctic natives, where white explorers and trappers, who persistently ate “southern” foods, died massively from the disease [3]. Early arctic explorers recognised the value of traditional Inuit dietary pattern of raw fish and meat, with only occasional ground plants and berries [4]. However, the vitamin C enigma is puzzling, certainly in the winter when no plant foods were present, and knowing that meat is usually cooked, with a loss of more than 50% of the present vitamin C.

Many theories have been developed to explain the absence of scurvy in Inuit communities. While many animals produce their own vitamin C, humans do not. It has been supposed that Inuit possessed L-gulonolactone oxidase enzyme, which is required in the last step of vitamin C synthesis from monosaccharides [1]. Although humans possess the gene for producing the necessary enzyme, it mutated to inactivity probably due to the high consumption of fruits and vegetables by early humans. Others assumed that

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a dietary pattern with frozen/raw, fermented and dried animal food would procure a minimum level of vitamin C required to prevent scurvy. A regular consumption of muttuk or mattak, i.e. epidermis of narwhal, and/or a higher tolerance for vitamin C insufficiency for Inuit have also been argued to explain the low incidence of scurvy in Inuit communities [1,2,5–8].

To investigate the sources of vitamin C in Inuit traditional dietary pattern, it is interesting to reanalyse older scientific data with contemporary standards. This task is not easy, because food was often recorded anecdotal. This was not the case for the Høygaard et al. files [5]. Høygaard et al. left Copenhagen in August 1936, and stayed in East-Greenland until August 1937. The centre of the research was located at the trading post at Tasiilaq, a settlement consisting of 57 natives and two West-Greenland families. However, the nutritional intake was analysed on a household level only, and not on an individual level. Luckily, Høygaard et al. published the raw data as supplement to their book [5].

The aims of the present study were to reanalyse the Høygaard et al. data according to modern scientific standards [5], to calculate individual vitamin C intake, and sources of vitamin C intake in a mid-1930 Inuit settlement in East-Greenland.

## Methods

### Participants

On 1 January 1937, the old “Angmagssalik” district counted 756 inhabitants living in 73 houses (Figure 1). Høygaard et al. concentrated their investigations at the places who had been most isolated and so least influenced by Western civilisation, but included five individuals living near trading centres. In total 35 adults clustered in 13 families were

selected: three individuals from Amituarsuk, two from Ikateq, four from Kulusuk, five from Qernertivartivit, nine from Sermiligaaq, and seven from Titeqilaq; five participants lived near trading centres, three from Igdlumuit and two from Tasiisq (trading centre). Household scales were used by the researchers to register consumption. Participating families were offered one krone per family.

### Assessment of nutrition

Before the start of the study, two researchers living with the families, weighed all the foods in the houses, whether it was imported or from traditional Inuit origin. New food brought into the house was immediately weighed. All given or received food gifts were registered, together with the blubber quantities used for the lamps, the dog food, and the food supply stored for later. When the study period was over, food quantities in the houses were weighed again. There was no interference from the researchers to induce the participants to other food than usually consumed. No foods were forbidden, but foods were usually weighed in a raw state. After cooking the remnants, mainly bones, were weighed again, and the weight was subtracted from the total weight before cooking.

The total number of days that food was recorded was 340, varying between 6 and 225 per family. To estimate individual food consumption from household food consumption, we used the adult-equivalent conversion factor from Claro et al. [9]. Total traditional and imported food estimates from households were divided by adult-equivalents calculated on the basis of the household composition as described by Høygaard et al. [5].

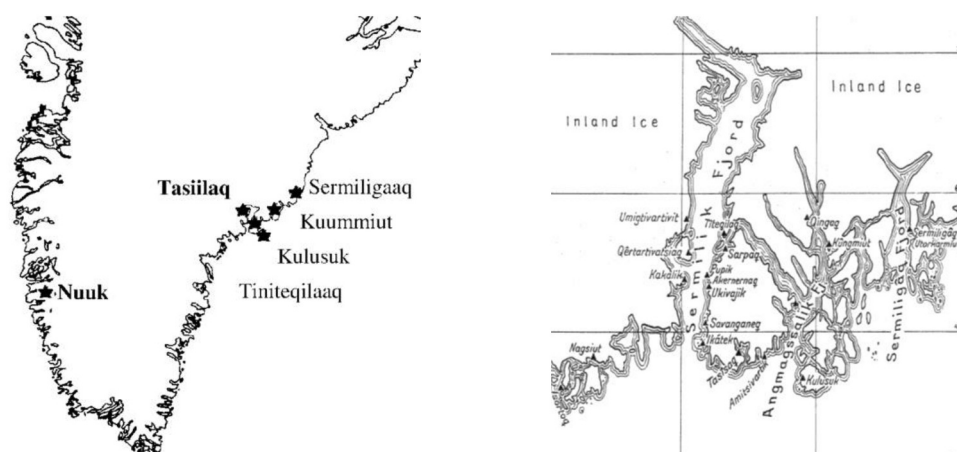


Figure 1. Locations in East-Greenland of the Høygaard study 1936–1937.

### Estimation of the nutritional composition of traditional foods

To estimate the food changes during cooking, the traditional way of Inuit cooking was repeated experimentally by Høygaard et al., and analyses were done before and after cooking. Between October and December Høygaard et al. dissected Fjord seals, cods, guillemot, and ducks. Meat, organs and blubber were weighed and analysed for composition. Vitamin C was determined by the method suggested by Emmerie and van Eekelen [10]. This method involves titration with 2–6 dichlorophenolindophenol after precipitation of cysteine, glutathione and ergothionine with mercuric acetate [10]. The vitamin C composition of imported food was calculated using McCance and Widdowson's Composition of Foods [11].

### Body weight and height

Weight and height were measured by the Høygaard team between September and October 1936. In absence of Body Mass Index (BMI) data in the Høygaard et al. study, we calculated the BMI using the following formula:  $BMI = \text{body weight (kg)}/\text{height (m)}^2$ .

### Statistics

All descriptive data are presented as median, and interquartile range (IQR) because data were not normally distributed. The data were analysed by using IBM SPSS statistics for Windows Version 27.0 (Armonk, NY: IBM Corp). All data were converted to 24 hours, expressed as  $d^{-1}$  (day).

### Results

Table 1 presents the general characteristics of the 21 males and 14 females of the Høygaard et al. study. Median (IQR) age was 35 (15) years for males, and 29 (9) years for females. Median (IQR) BMI was 25 (1)  $\text{kg}/\text{m}^2$  for males and 25 (3)  $\text{kg}/\text{m}^2$  for females. At the time of the study, only 14% of the participants lived near a trading station.

Table 2 presents the vitamin C content in mg per 100 g traditional Inuit foods as determined by Høygaard et al. The vitamin C content varied between 0 mg for blubber and 127 mg for adrenal glands. In general, the vitamin C content of meat is much lower than in organs, seals meat, for example, contains only 2 mg per 100 g compared with 10 to 20 mg for organs. High vitamin C concentrations can be found in some marine plants like *Alaria pylaii* with 44 mg for 100 g.

**Table 1.** Baseline characteristics of the 35 participants (Høygaard Study 1936–1937).

	Males (n = 21)		Females (n = 14)	
	Median	IQR	Median	IQR
Age (years)	35	15	29	9
Height (cm)	162	2	156	3
Weight (kg)	65	2	62	4
Body Mass Index ( $\text{kg}/\text{m}^2$ )	25	1	25	3
Number of days food records	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
From 1 to 10 days	13	62	7	50
From 11 to 20 days	7	33	7	50
More than 20 days	1	5	0	0
Living place in East-Greenland	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
Amituarsuk	1	4	2	14
Ikateq	2	10	0	0
Kulusuk	2	10	2	14
Qernertivartivit	3	14	2	14
Sermiligaq	6	29	3	22
Titeqilaq	4	19	3	22
Igdiumiut (trading station)	2	10	1	7
Tasisaq (trading station)	1	4	1	7

IQR = Interquartile range

**Table 2.** Vitamin C (mg/100 g) in East-Greenland traditional foods (Høygaard Study 1936–1937)\*.

Food	Vitamin C (mg/100 g)	Food	Vitamin C (mg/100 g)
Fjord seal		Guillemot	
Adrenal	127	Liver	22
Thymus	26	Brain	16
Liver	18	Eye	9
Brain	18	Intestine	5
Epididymis	17	<b>Eider duck</b>	
Kidney	13	Liver	17
Eye	10	Eye	14
Lymph gland	7	Brain	9
Pancreas	7	Intestine	4
Ovary	7	<b>Invertebrates</b>	
Skin	3	Blue mussel	6
Small intestine	3	<b>Cod</b>	
Blood	3	Liver	9
Meat	2	Meat	2
Heart	2	Roe	44
Blubber	0	Cod liver oil	0
<b>Plants</b>		<b>Marine plants</b>	
Roseroot	27	<i>Alaria pylaii</i>	44
Mountain willow	18	<i>Rhodymenia palmata</i>	17
Dandelion leaves	15	<i>Fucus spp</i>	13
Crowberries	9	<i>Ascophyllum nodosum</i>	11
<b>Narwhal</b>		<b>Polar bear</b>	
Meat	1	Meat	4
Blubber	0	Blubber	0
Liver	23	<b>Greenland shark</b>	
Epidermis	20	Meat	1

\*All data were extracted from the Høygaard manuscript (see Method section for determination of vitamin C content in traditional foods).

Fjord seal eye and muktuk or mattak, traditionally seen as rich in vitamin C and antiscorbutic, contain 10 and 20 mg vitamin C for 100 gr, respectively.

Median (IQR) vitamin C intake was 79 (77)  $\text{mg}\cdot\text{day}^{-1}$  for males and 59 (56)  $\text{mg}\cdot\text{day}^{-1}$  for females (Table 3). Approximately 50% of the vitamin C came from animal

**Table 3.** Vitamin C intake of the 35 adult participants (Høygaard Study 1936–1937).

	Males (n = 21)		Females (n = 14)	
	Median	IQR	Median	IQR
<b>Crude vitamin C (mg)</b>	79	77	59	56
From animals*	36	32	30	14
From plants	37	73	28	60
From traditional foods	79	77	59	56
From imported foods	0	0	0	0
From seal	21	31	21	28
From fish	14	31	6	24
From algae	21	27	19	43
From narwhal skin (muktuk or mattak**)	0	4	0	3
From eyes	0.3	0.5	0	0
From organs	14	11	16	12
<b>Number of persons consuming</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
Algae	14	67	10	71
Narwhal skin (muktuk or mattak)**	5	24	3	21
Eyes	17	81	13	93
Plant foods (without algae)	13	62	8	57
Organs	18	86	11	79
<b>Distribution of vitamin C intake</b>	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>
0 to 10 mg/d <sup>-1</sup>	1	5	1	7
11 to 20 mg/d <sup>-1</sup>	0	0	0	0
More than 20 mg/d <sup>-1</sup>	20	95	13	93

\* Høygaard et al. found a mean of 50% loss when cooking

\*\* Muktuk or mattak was two or three days old when vitamin C was determined

IQR = Interquartile range

foods, where Høygaard et al. found a 50% loss when cooked. This would bring median intake from animal food to 18 mg for males and 15 mg for females. Consumption of meat and organs from seals gave 21 mg.d<sup>-1</sup> vitamin C, comparable to vitamin C from algae. Narwhal skin and eyes had a marginal contribution to the vitamin C consumption. The number of adults consuming algae during the research days was 67% for males and 71% for females, this was only 24% and 21% for narwhal skin. Eyes were consumed by 81% of the males and 93% of the females, and organs by 86% and 79% respectively. Almost all vitamin C daily intake was higher than 20 mg.d<sup>-1</sup>.

## Discussion

The main conclusion of the present study is the important role of algae consumption in East-Greenland traditional dietary pattern as source of vitamin C. Secondly, foods traditionally seen as important sources of vitamin C like eyes from seals and narwhal skin, played probably a minor role in avoiding scurvy.

Comparing the results of this study with other studies is difficult because of the lack of data. In the past, the arctic explorer Vilhjálmur Stefánsson cured three cases of scurvy in 1918 in only three weeks with a diet of boiled and frozen meat [4]. In view of the low quantity of vitamin C in boiled meat, it is highly probable that only frozen and unboiled meat was

responsible for the curing effect and this in high quantities to meet the vitamin C requirements. The curing would have been easier with organs, with a higher vitamin C content. It is also not clear from the reports of early explorers if they consumed organs or cooked meat alone [1]. Assuming 2 mg for 100 g seals meat, and a loss of 50% during cooking, a minimum of 1 kg meat a day would be necessary to reach the 10 mg.d<sup>-1</sup> vitamin C to avoid scurvy.

The high vitamin C content of algae was confirmed by Van Eekelen et al. in 1933; they found 43 mg in *Fucus serratus* and even 77 mg in *Fucus vesiculosus* [5]. Lunde et al. found between 8 and 46 mg in brown algae, and higher quantities in algae growing near the surface of the sea [5]. Moreover, algae stored in blubber bags contained even after months considerable quantities of vitamin C. According to Høygaard et al., algae were much more consumed between September and December, and plant foods during the rest of the year [5]. In 1671 Bartholini reported that scurvy grass, i.e. probably *Cochlearia officinalis*, was used as remedy against scurvy on the west coast of Greenland [5]. The French explorer Paul-Emile Victor, who was in East-Greenland during the same period as Høygaard et al., described in a book how the Inuuk Kristian and he suffered from scurvy [12]. Interestingly, the story is confirmed by Høygaard et al. [5]. On 26 April 1937, Paul-Emile Victor was unable to eat due to pains in the gums, which aggravated his scurvy complaints, meanwhile Kristian consumed algae and raw meat. A week later, Kristian's mouth affection improved, while Paul-Emile Victor became worse. On 8 May 1936, Paul-Emile Victor was received at the hospital with almost 0 mg.dl<sup>-1</sup> vitamin C in blood, while normal values are estimated around 0.2 to 2.0 mg.dl<sup>-1</sup>. From May 9<sup>th</sup> on Paul-Emile Victor received 500 mg.d<sup>-1</sup> vitamin C, and left the hospital on May 17<sup>th</sup>. On May 13<sup>th</sup> Kristian was examined, he had no more signs of scurvy. This case confirms the role of algae in the cure of scurvy.

The traditional Inuit food system was extremely dependent on game, which on his turn depended on the sea currents, drift ice and the occurrence of plankton. A year with extreme pack ice could ruin the hunting season with starvation as a consequence. Moreover, mattak or muktuk was seen by early explorers as an important source of vitamin C, but the consumption was very low and depending on the hunt. Secondly, seals eyes were also seen as sources of vitamin C, but an eye, usually consumed raw, weighted only 33 g, which is 3 mg vitamin C, too low to feed a community [5]. A person would need three eyes a day to reach 10 mg vitamin C and avoid scurvy, which represents 1.5 seal a day!

It is difficult to have an idea of the prevalence of scurvy in East-Greenland in 1936–1937 [5]. According to Høygaard et al., severe scurvy was unknown in the area under study, but sub-scurvy cannot be excluded in view of the chronic gingivitis observed by Høygaard et al. in the spring. Høygaard et al. performed 34 blood determinations of vitamin C, 18 between November and April, and 16 between July and August. In total 12 (35%) observations were between 0.5 and 1.2 mg.dl<sup>-1</sup>, 16 (47%) around 0.4 mg.dl<sup>-1</sup> and 6 (18%) less than 0.3 mg.dl<sup>-1</sup>. The reported vitamin C blood determinations reflect hypovitaminosis C for 47% of the sample, and scurvy levels for 18% of the population. Despite the fact that, according to Høygaard et al., clinical scurvy was not present, and probably not observed by early explorers, but it is highly probable that Inuit with a traditional nutrition lived on the edge of scurvy. It is remarkable that all 6 with extreme low blood concentrations of vitamin C, lived near the trading centre consuming more imported food and less traditional food.

Delanghe et al. hypothesised that vitamin C deficiency is more than a nutritional disorder [13]. A genetic protection against scurvy could be present due to the unique haptoglobin phenotype distribution present in the Inuit population, which could be an important non-nutritional modifying element in the pathogenesis of scurvy by its greater capacity to inhibit oxidation and limiting vitamin C depletion.

The most important limitation of the present study, is that converting household consumption to individual consumption will obscure differences in intake among people of differing age and body weight, and that members of households do not participate to the study. A source of unavoidable error for Høygaard et al. was eating when hunting. It was impossible to prevent the members of a family to hunt and/or to forbid eating during a successful hunting with colleagues. This quantity could not be estimated and will introduce an error mainly on male consumption.

During the arctic explorations, many sailors died from scurvy, after a horrible agony. The apparition of petechiae and bleeding gums were the announcement of a painful end. Harvested or cultivated algae on board could have saved many lives, knowledge that could be obtained from empirical observation of Inuit traditional dietary pattern, but they died in a sea of algae.

As conclusion to the present study, a reanalysis of older nutritional data in a modern and standardised way can be interesting to better understand traditional

nutritional systems in general, and of East-Greenlandic Inuit in this case. In this study, the main conclusions are the important role of algae consumption in Inuit traditional dietary pattern to avoid scurvy, and that foods traditionally seen as important sources of vitamin C like eyes from seals and narwhal skin, play a minor role in meeting the vitamin C requirements.

## Disclosure statement

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

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