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Nutritional Qualities of Ooligan Grease: A Traditional Food Fat of British Columbia First Nations

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Food composition including moisture, total fat, cholesterol, vitamin A, calcium, iron, zinc, fatty acids, and four heavy metals were measured in the traditional fish fat, *ooligan grease* and in ooligan fish (*Thaleichthys pacificus*), collected from five First Nations communities (Nass River, Kitimaat, Bella Coola, Kingcome Inlet, and Knights Inlet) in the coastal area of British Columbia, Canada. There were few differences in nutrient composition of ooligan grease collected from different sites. Ooligan fish and extracted grease had mean fat contents of 18.0% and 98.0%, respectively. Cholesterol in ooligan grease was 197 ± 76 mg/100 g. Ooligan grease was a rich source of vitamin A (2000 ± 1200 RE/100 g wet weight) and omega-3 fatty acids (19 ± 4.4 g/100 g), but had less vitamin A compared to raw fish (3200 RE/100 g). However, there was a 10-fold increase of omega-3 fatty acid in grease compared to ooligan fish fat which may be attributed to microbial conversion of other fatty acids to docosahexaenoic acid during ooligan grease preparation. Ooligan fish, usually consumed whole, are a good source of calcium (300 ± 74 mg/100 g), iron (1.8 ± 0.4 mg/100 g), and zinc (1.6 ± 0.4 mg/100 g). Mean heavy metal concentrations in ooligan grease were 140 ± 12 μg/100 g arsenic, 1.8 ± 0.5 μg/100 g cadmium, 0.3 ± 0.1 μg/100 g mercury, and 2.0 ± 2.6 μg/100 g lead. These concentrations are below guidelines established by Health Canada and Agriculture Canada.

INTRODUCTION

Food fats derived from marine species have been important in many indigenous cultures. In Canada, processed fats from whale, walrus, seal, and several fish have been documented in the ethnographic and nutritional literature (Eidlitz, 1969; Kuhnlein *et al.,* 1982; Kemp, 1984; Kinloch *et al.,* 1992). The understanding of the significance of fish oils and lipids, and their potential contribution to the prevention of chronic disease has been the subject of extensive research in the last two decades (McNamara, 1992). That Indigenous Peoples have used and have highly appreciated fats from a variety of wildlife species within their historical cultures is an indication that these foods have much to their credit in aesthetic as well as nutritional considerations (Kuhnlein *et al.,* 1982; Appavoo *et al.,* 1991; Kuhnlein *et al.,* 1991).

For First Nations Peoples of British Columbia the marine food fat that is most highly renowned is that rendered from the small smelt-like fish *Thaleichthys pacificus.* In local languages, these fish are referred to as eulachon, eulachen, olachen, olachon, oolachan, or ooligan (Kuhnlein *et al.,* 1982). Several ethnographic accounts of the preparation of ''ooligan grease'' by many peoples of the British Columbian coast demonstrate the universality and popularity of this food (Curtis, 1915; Boas, 1916;

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Barnett, 1955; Hawthorne *et al.,* 1960; Garfield and Wingate, 1966; Rohner, 1967; Macnair, 1971; Oberg, 1973; Stewart, 1975; Kuhnlein *et al.,* 1982). Ooligan grease is known by Indigenous Peoples as a condiment for many different food such as dried salmon, potatoes, wild berries, native root foods, and vegetables. As a food it is also used as an ingredient in soups, stews, breads, and as a medium for frying bread, as well as a preserving agent for dried foods, protecting from oxidation, and pests. It is known as a medicine for the treatment of various ailments, such as skin rashes, intestinal disorders, tuberculosis, and flu. Used as food, medicine, wood and leather lubricant, and an important trade item and gift, the cultural significance of ooligan grease cannot be underestimated (McIlwriath, 1948; Garfield and Wingate, 1966; Rohner, 1967; Niblack, 1970; Turner, 1975; Edwards, 1978; McGregor, 1981).

Ooligan grease is prepared from the ooligan by cultural processes that include netting the fish in bulk and permitting them to ''ripen'' in outdoor bins to develop the flavor and permit decomposition of the carcass for easy release of the fat during cooking. Ethnographies describe various ways for cooking the fish in water heated to near-boiling and subsequent straining, reheating, bottling, and storage (Kuhnlein *et al.,* 1982).

Earlier work documented the preparation of ooligan grease by several families from the Nuxalk Nation in Bella Coola, BC, and its basic composition. In this area, each family grease preparation represented the harvest and preparation of approximately 6300 kg of fish, yielding 380 pounds of prepared grease. Vitamin A, Vitamin E, and Vitamin K were shown to be present in significant amounts and exceeding that in fats commercially processed and marketed (Kuhnlein *et al.,* 1982).

In this study, we further explored the nutrient composition, in particular the fatty acid profile, of ooligan grease prepared from different First Nations communities. We also studied possible changes to the nutrient contents and fatty acid profiles due to the grease rendering process and other fish preparation methods, such as smoking and drying, commonly adopted by the people in different areas of the British Columbia coast. Because of the concern of contamination of the traditional food system by environmental pollutants, we also determined levels of heavy metals including arsenic, cadmium, lead, and mercury.

MATERIALS AND METHODS

Sample Collection

In the season of ooligan spawning and the traditional preparation period for ooligan grease, we collected 19 samples of ooligan grease from independent First Nations family preparations, and about 60 samples of small dried, smoked, and frozen ooligan fish from five primary First Nations areas. These areas, from North to South on the coast of British Columbia were Nass River (five samples), Kitimaat (five samples), Nuxalk Nation at Bella Coola (five samples), Kingcome Inlet (three samples), and Knights Inlet (three samples) (Fig. 1). The samples were collected during March–April, 1994. The grease samples were preserved in sealed cans and fish samples were bagged in plastic sampling bags. All samples were frozen at −23°C until shipment to the laboratory.

Each grease sample was collected from one family of the particular community. Therefore, even though the total number of grease samples was small, when using the average fish harvested per family preparation in Bella Coola, they represent extract from over 11,000 kg of fish (Kuhnlein *et al.,* 1982). Since the focus of this study was

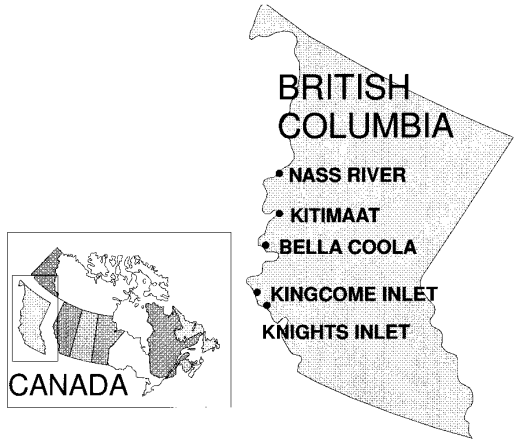

FIG. 1. Map of the sampling sites: Nass River, Kitimaat, Bella Coola, Kingcome Inlet, and Knights Inlet, in British Columbia, Canada.

on ooligan grease, analyses of fish were performed on composite samples from each of the three communities.

Sample Preparation

Ooligan grease samples were thawed at 60°C in a water bath and mixed well. Fish samples were prepared by pooling five whole fish from the same site; these were allowed to thaw slightly and were then homogenized in a blender into a consistent paste.

Chemicals and Standards

Gas chromatography (GC) or high performance liquid chromatography (HPLC) grade acetone, hexane, petroleum-ether (40–60°C), chloroform, and methanol were obtained from Fisher Scientific (Montreal, QC). Omnisolv grade heptane and isopropyl alcohol and all other reagents, unless otherwise specified, were obtained from BDH Chemicals (VWR, London, ON). Fatty acid methyl ester (FAME) standards GLC-411 were obtained from Nu Chek Prep Inc. (Elysian, MN).

Moisture Analysis

Moisture contents of grease samples were determined by vacuum oven drying at 70°C at a negative pressure of 25 in. Hg for 36–48 h. Moisture contents of fish samples were determined by freeze-drying for 24–30 h using a Flexi-Dry MP system (FTS systems, Stone Ridge, NY); these were then vacuum oven dried to constant weight at 60°C at 25 in. Hg negative pressure.

Total Crude Fat Determination

Total crude fat was extracted using the AOAC method 948.16 (1995), the acetone extraction method. Approximately 3 g of dry homogenized samples were preextracted with acetone for 45 min (20 min in boiling position and 25 min in rinse position)

TABLE 1

NUTRIENT COMPOSITION OF PREPARED OOLIGAN GREASE AND FISH COMPOSITES FROM BRITISH COLUMBIA

	Grease[a]	Raw Fish[b]	Dried Fish[b]	Smoked Fish[b]
Fat (%)	98.0 ± 0.8	16.7	15.5	21.9
Moisture (%)	1.4 ± 0.9	72.2	69.6	59.2
Retinol (RE/100 g wet weight)	2400 ± 1200	3196	2021	4439
Retinol (RE/100 g lipid)[c]	2500 ± 1200	25776	14330	18345
Cholesterol (mg/100 g wet weight)	200 ± 76	109	84	124
Cholesterol (mg/100 g lipid)	200 ± 78	656	557	565

[a] n=19
[b] Composite samples of five fish.
[c] Values estimated from fat content of sample.

with an automatic soxhlet system (Soxtec HT-6, Tacater AB, Hoganas, Sweden). The solvent in the extraction cups was evaporated in a vacuum oven (70°C and 25 in. Hg negative pressure) for 30 min and weighed to calculate the percentage fat. The residual samples in the extraction thimbles were dried (70°C and 25 in. Hg negative pressure) for 15 min to expel any solvent and transferred into boiling flasks. A total of 40 ml of 4 *N* HCl was added to each sample and digested at 100°C for 1 h. The digests were filtered, washed with hot distilled water, and dried for 90 min. The dried residue were transferred into the thimbles and reextracted with acetone for 45 min (20 min in boiling position and 25 min in rinse position). The percentage fat was determined as described above. Total crude fat was calculated as the sum of the percentage fat after preextraction and hydrolysis (AOAC, 1995).

Fatty Acid Analysis

Approximately 0.5 g of the grease sample of 1 g of fish homogenate was weighed into 50-ml centrifuge tubes and extracted with 18 ml of chloroform:methanol mixture (2:1) by sonication for 30 min. Five milliliters of saturated aqueous sodium chloride (NaCl) were then added. The final mixture was vortexed and centrifuged at 2000 rpm for 5 min. Aliquots (2 ml) of the lower chloroform layer were evaporated to dryness under a gentle stream of nitrogen.

Fatty acids were analyzed as their methyl esters (FAME). The derivatization was done with a modification of the boron fluoride-methanol ($BF_3 \cdot MeOH$) method of Morrison and Smith (1961). The derivatization reagent (4:3:4 $BF_3 \cdot MeOH$:benzene:methanol) was added to the dry lipid residue in a 15-ml centrifuge tube (1 ml/10 mg lipid residue), flushed with nitrogen, capped tightly, and incubated in a

TABLE 2

FAT AND FATTY ACIDS IN OOLIGAN GREASE AND FISH COMPOSITES

a			Saturated Fatty Acids (g/100 g lipid)			
Site	N	Crude Fat[a]	14:0	16:0	18:0	Total
GREASE						
Nass River	5	98 ± 0.5	4.2 ± 0.7	12 ± 1.8	2.1 ± 0.4	18 ± 2.8
Kitimaat	5	99 ± 0.7	4.6 ± 0.5	12 ± 1.1	4.0 ± 3.4	21 ± 2.5
Bella Coola	5	99 ± 1.1	4.5 ± 0.7	12 ± 1.6	2.3 ± 0.4	19 ± 2.6
Kingcome Inlet	1	97.5	4.6	12.7	2.2	19.5
Knights Inlet	3	99 ± 1.4	5.4 ± 0.9	12 ± 2.1	2.6 ± 0.3	20 ± 3.2
FISH COMPOSITE[b]						
Nass River (dried)	1	15.5	5.5	15.9	3.5	24.9
Bella Coola (smoked)	1	21.9	6.4	16.7	3.9	27.1
Knights Inlet (raw)	1	16.7	5.3	14.7	3.6	23.5

[a] g/100g wet weight
[b] Composite samples of five fish.

b	Monosaturated Fatty Acids (g/100 g lipid)						
Site	16:1	18:1 Oleate	18:1 Vaccinate	20:1 (5-Eicos)	20:1 (11-Eicos)	22:1	Total
GREASE							
Nass River	4.6 ± 0.8	25 ± 3.7	3.4 ± 0.6	0.2 ± 0.04	0.3 ± 0.1	ND	33 ± 5.2
Kitimaat	4.8 ± 0.5	27 ± 3.2	3.4 ± 0.3	Tr[a]	0.3 ± 0.1	ND	36 ± 3.9
Bella Coola	4.3 ± 0.9	28 ± 4.3	3.2 ± 0.7	0.3 ± 0.04	0.3 ± 0.1	ND	36 ± 5.8
Kingcome Inlet	5.2	27.3	3.7	0.2	0.4	ND	36.7
Knights Inlet	5 ± 1.5	34 ± 3.6	4 ± 1.0	Tr[a]	0.5 ± 0.1	ND	43 ± 6.2
FISH COMPOSITE[b]							
Nass River (dried)	5.6	36.2	4.2	ND	0.2	0.1	46.2
Bella Coola (smoked)	6.0	43.7	5.0	ND	0.1	0.1	54.8
Knights Inlet (raw)	5.0	38.5	3.9	ND	0.03	0.01	47.5

ND Not detectable
[a] Trace amounts <0.01 g/100 g wet weight.
[b] Composite samples of five fish.

water bath at 100°C for 45 min. The FAME were extracted into 2 ml of hexane. Aliquots (250 μl) of the hexane extract were spiked with an internal standard (C17:0 methyl ester) and analyzed by GC. GC analysis was performed using a 30-m supelcowax-10-fused capillary column (0.32 ID, 0.25 mm film thickness), fitted on a Varian Star 3400 CX chromatograph (Varian Inc., Walnut Creek, CA). Separation was achieved with the following temperature program: initial column temperature at 80°C; initial hold time was 1 min; final column temperature was 220°C; rate, 15°C/min; final hold time was 25 min. Helium was used as the carrier gas at a flow rate of 2 ml/min. Injection was performed in the split mode (1:50) using an automatic injector (Varian 8200 CX). Quantification was performed with the Varian Chromatographic Work Station Software (Ver-4), using a 5-point calibration curve. A fatty acid standard mixture containing 32 fatty acids from Nu Chek

TABLE 2—*Continued*

c	Omega-6 Polyunsaturated Fatty Acids (g/100 g lipid)			
Site	18:2ω6	20:3ω6	20:4ω6	Total
GREASE				
Nass River	0.4 ± 0.1	0.4 ± 0.1	0.6 ± 0.2	1.4 ± 0.3
Kitimaat	0.4 ± 0.04	0.5 ± 0.1	0.1 ± 0.1	0.9 ± 1.0
Bella Coola	0.6 ± 0.5	0.3 ± 0.1	0.2 ± 0.1	1.1 ± 0.4
Kingcome Inlet	0.5	0.4	0.7	1.6
Knights Inlet	0.4 ± 0.1	0.4 ± 0.2	0.3 ± 0.2	0.9 ± 0.5
FISH COMPOSITE[a]				
Nass River (dried)	0.3	1.2	0.7	2.2
Bella Coola (smoked)	0.2	1.5	0.6	2.3
Knights Inlet (raw)	0.2	1.2	0.6	2.0

[a] Composite samples of five fish.

d	Omega-3 Polyunsaturated Fatty Acids (g/100 g lipid)				
Site	18:4ω3	20:5ω3	22:6ω3	Total	P:S:M[a]
GREASE					
Nass River	0.4 ± 0.1	0.5 ± 0.1	23 ± 6.7	23 ± 6.6	1.4:1.0:1.8
Kitimaat	0.3 ± 0.1	0.7 ± 0.1	18 ± 3.9	19 ± 4.0	1.0:1.0:1.7
Bella Coola	0.2 ± 0.1	0.4 ± 0.2	22 ± 7.0	21 ± 6.8	1.2:1.0:1.9
Kingcome Inlet	0.3	0.3	20.2	20.9	1.2:1.0:1.9
Knights Inlet	0.4 ± 0.3	0.9 ± 0.5	11 ± 5.9	12 ± 5.1	0.6:1.0:2.1
FISH COMPOSITE[b]					
Nass River (dried)	0.5	2.2	0.9	3.6	0.2:1.0:1.9
Bella Coola (smoked)	0.6	2.0	1.0	3.5	0.2:1.0:2.0
Knights Inlet (raw)	0.4	2.0	1.2	3.6	0.2:1.0:2.0

[a] The P:S:M ratio was calculated by dividing the summed polyunsaturated fatty acids and summed monounsaturated fatty acids, respectively, by the summed saturated fatty acids which were considered as 1.0.
[b] Composite samples of five fish.

Prep (Product No. GLC-411, Nu Chek Prep, Inc., Elysian, MN) and C18:4 and C20:5 from Sigma Chemical Co. (St. Louis, MO) was used as external standard. All identified peaks were quantified.

Cholesterol Analysis

Cholesterol was determined by gas chromatography using a modification of AOAC method 970.51 (AOAC, 1995). Approximately 0.5 g of lipid samples were weighed into 15-ml centrifuge tubes, and 5 ml of absolute ethanol and 500 μl of 60% KOH solution were added. The tubes were flushed with nitrogen and capped tightly with

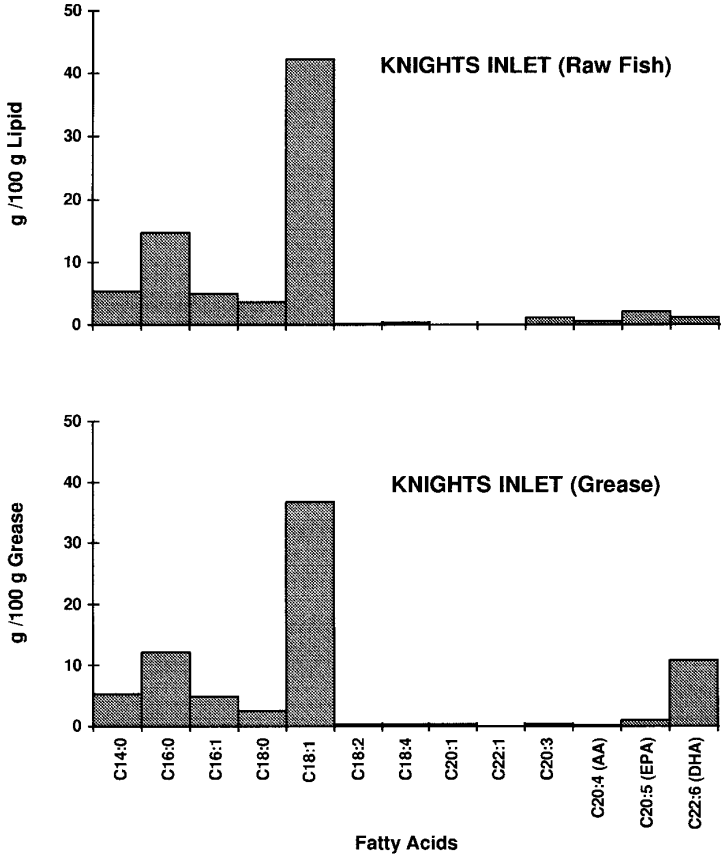

FIG. 2. Comparison of fatty acid profiles of ooligan fish and ooligan grease collected from Knights Inlet.

Teflon-lined caps. The samples were digested in a dry bath at 100°C for 3 h. The digests were allowed to cool to room temperature and 3 ml of aqueous NaCl were added and vortexed. The final digests were extracted with 3 × 10 ml of diethyl ether. The ether layers were pooled together in 50-ml centrifuge tubes and washed with distilled water. The ether layer was recovered by centrifugation and evaporated to dryness under a gentle stream of nitrogen. The residues were reconstituted in hexane (2 ml), spiked with an internal standard (5-a-cholestane) at 1 mg/ml, and analyzed by GC. GC was performed on XTI-5 (30 m × 0.25 mm ID, 0.25 μm film thickness) (Chromatographic Specialities, Brockville, ON). Cholesterol was identified by retention time against a cholesterol standard.

Retinol Analysis

Approximately 5 g of grease or 10 g of fish homogenate was weighed into round bottomed flasks and digested with 2% ethanolic pyrogallol (40 ml) and 10% ethanolic potassium hydroxide (KOH) (40 ml) by refluxing for 30 min under gentle boiling. The digests were allowed to cool and then filtered through glass wool into a 250-ml umber volumetric flask and made up to volume with absolute ethanol. Aliquots of the well-mixed digest (2 ml) at room temperature were transferred into 15-ml centri-

TABLE 3

FATTY ACID PROFILES OF OOLIGAN GREASE LIPID AND FISH OIL EXTRACT

	Ooligan Grease Lipid Extract		Ooligan Fish Oil Extract	
Fatty Acid	g/100 g lipid[a]	% of total fatty acids	g/100 g lipid[b]	% of total fatty acids
14:0	4.6 ± 0.4	6.1	5.7 ± 0.5	7.2
16:0	12.1 ± 0.3	15.8	15.6 ± 0.9	19.8
16:1	4.7 ± 0.3	6.2	5.5 ± 0.4	6.9
18:0	2.6 ± 0.7	3.4	3.6 ± 0.2	4.6
18:1	32 ± 3.4	41.3	43 ± 4.0	53.7
18:2	0.5 ± 0.1	0.6	0.2 ± 0.1	0.3
18:4	0.3 ± 0.1	0.4	0.5 ± 0.1	0.7
20:1	0.6 ± 0.1	0.6	0.1 ± 0.1	0.2
20:3ω6	0.4 ± 0.1	0.5	1.3 ± 0.03	1.7
20:4(AA)	0.4 ± 0.2	0.5	0.7 ± 0.1	0.8
20:5(EPA)	0.6 ± 0.2	0.7	2.1 ± 0.1	2.7
22:6(DHA)	18 ± 4.4	23.9	1.1 ± 0.3	1.4

[a] mean ± SD, n=19
[b] mean ± SD, n=4

fuge tubes with Teflon caps (three replicates per digest); 3 ml of deionized water were added to each tube which was then vortexed. Each tube was extracted four times with 5 ml peroxide-free diethyl ether-hexane mixture (15:85). The upper organic layers were pooled together into 50-ml boiling tubes. The retinol extract was evaporated to dryness under a gentle stream of nitrogen at 60°C, redissolved in 1 ml heptane, transferred into umber sample vials, flushed with nitrogen, and capped immediately. Each batch of six digestions included a standard control sample (chicken liver homogenate) and a retinol in soy oil standard to evaluate recovery and reproducibility.

Retinol was analyzed by normal phase HPLC on a silica column (Supelcosil 15 cm × 4.6 mm) (Supelco Inc., Bellefonte, PA) fitted to a Beckman Gold HPLC System (Beckman HPLC module 126, Beckman Inc., Fullerton, CA). A duplicate sample of 32 μl of the retinol extract was injected by an automatic injector (Gilson 401 dilutor, Gilson Medical Electronics Inc., Middleton, WI). Isopropanol (0.6%) in heptane was used as the mobile phase (flow rate was 2 ml/min). Peaks were detected at 325 nm with a diode array detector (Beckman Module 168).

Quantitation was performed with the Beckman gold Ver-7 Software using a 9-point calibration curve with the external standard calibration mode. The all-*trans*-retinol standard (Sigma R 7632) used was further purified in-house by normal phase HPLC as described above. The concentration of retinol calibration standards were calculated using the absorbance at 325 nm with a known extinction coefficient of 1830 for all-*trans*-retinoic acid. The HPLC system was calibrated daily with triplicate injections of a retinol working standard in cottonseed oil.

A sockeye salmon sample, a soya oil sample, and a cotton seed oil working sample were analyzed with each sample batch; reproducibility was within 95%. Selected

samples were spiked with a pure retinol standard; the recovery rate was always above 95%.

Mineral and Heavy Metal Analysis

Approximately 1 g of grease sample of 2 g of fish homogenate was weighed into acid-washed 50-ml boiling tubes (two replicates per sample) and dried to constant weight. Two milliliters of 70% nitric acid (JT Baker Instra-analyzed, from Canlab Div., Mississauga, ON) were added to each sample and digested at 50°C for 12 h. Digests were allowed to cool to room temperature, and an additional 2 ml of HNO_3 was added to each and digested for another 12 h at 100°C, till a clear solution was obtained. Final digests were allowed to cool to room temperature and made up to 10 ml with deionized water. Calcium, iron, and zinc were determined by atomic absorption spectrometry (AAS) on the flame mode. Arsenic, cadmium, and lead were determined by graphite-furnace AAS and mercury was analyzed by the cold vapor method. All were determined with a Hitachi Z-8200 Zeeman polarized atomic absorption spectrophotometer (Nissei Sanyo Ltd, Mississauga, ON).

Two sample blanks were analyzed together with each batch of samples. Concentrations in blanks were below the detection limits in all analyses. A spiked blank was analyzed during each analysis to ensure day to day reproducibility. Each standard and sample was measured in duplicate and the sample was reanalyzed if the relative standard deviation of the two measurements was higher than 5%. Coefficients of variations of the three replicates of the samples for all seven analyses were generally less than 10%; the mean was used as the representative value for the sample. Standard reference materials from the National Institute of Standard & Technology (oyster tissue SRM 1566a, apple leaves SRM 1515 and bovine liver SRM 1577b) were digested and analyzed with each batch of samples. Results of the mineral and heavy metal concentrations always fell within 1 SD of the certified values. Our laboratory participated in interlaboratory comparison with the Arctic Environmental Strategy of the Department of Indian and Northern Affairs Canada.

RESULTS AND DISCUSSION

Results for levels of moisture, total fat, retinol, and cholesterol in grease and fish samples are summarized in Table 1. Results of moisture and fat contents parallel those reported earlier for ooligan grease collected from the Nuxalk Nation in Bella Coola (Kuhnlein *et al.,* 1982). Grease contained more than 98% fat and small amounts of moisture (about 1%). Results of moisture composition of fish samples showed that extraction methods used by different First Nations were similarly efficient in removing water from the grease. For fish, the smoking process was more effective in dehydrating the fish for preservation than open-air drying. This could be partly due to relatively cool and humid weather conditions in early spring when ooligan fish are harvested.

Raw ooligan fish contained approximately 16.7% fat, which was similar to levels of other fatty marine fish, such as mackerel (Health and Welfare Canada, 1987). Prepared ooligan fish, particularly smoked fish, had higher amounts of fat (21.9%) than did raw fish (16.7%), smoked chinook salmon (4.2%), or smoked cisco (12%) (Health and Welfare Canada, 1987). Cholesterol in ooligan grease was high (197 $\pm$ 76 mg/100 g), similar to that in melted butter (219 mg/100 g).

Results of vitamin A analysis showed that ooligan grease was rich in vitamin A (mean RE 2400/100 g; range 2000–4400). The average value was similar to that

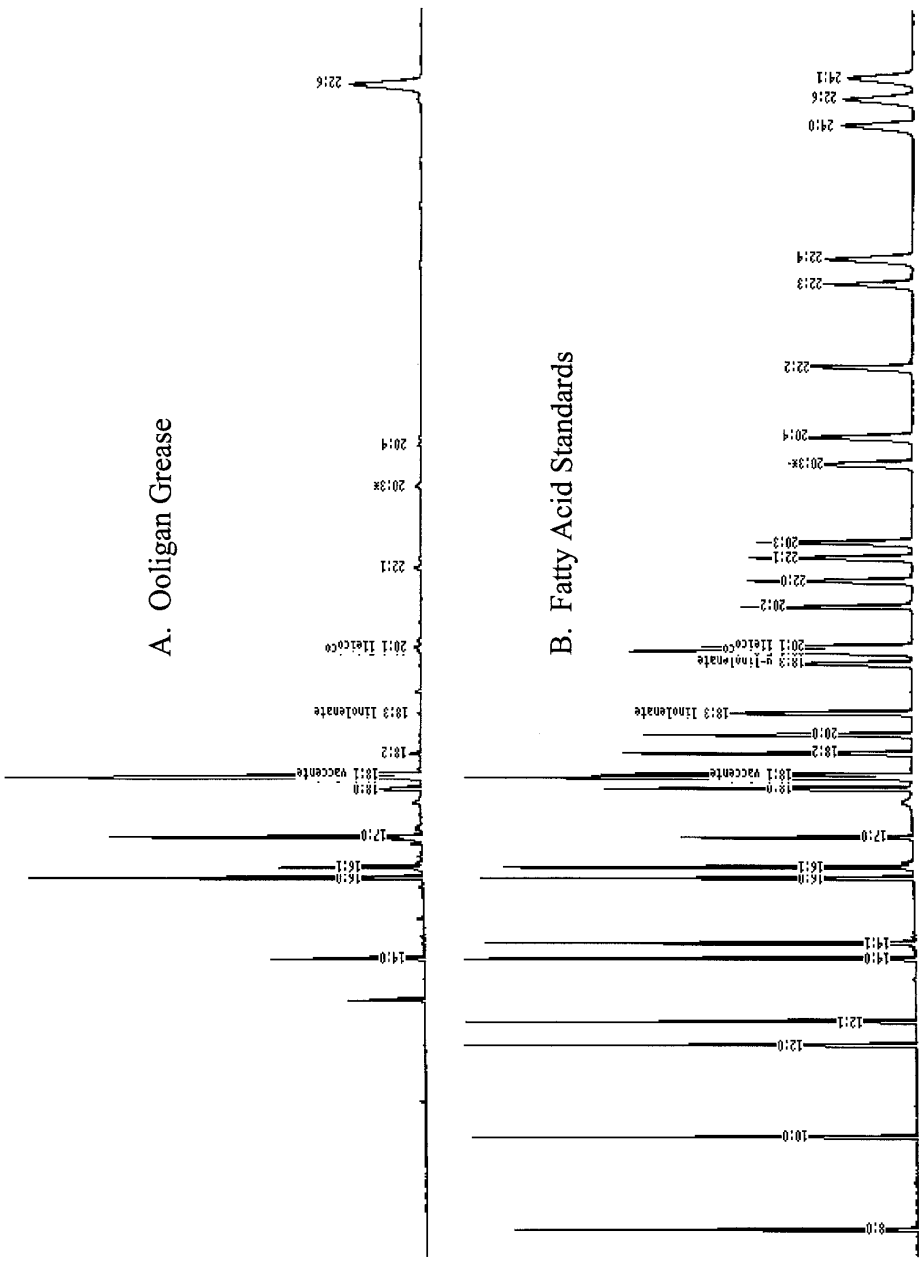

FIG. 3. Typical chromatograms of ooligan grease and fatty acid standards. Around 15 to 20 peaks were identified and quantified.

TABLE 4

CONCENTRATIONS OF CALCIUM, IRON, AND ZINC IN OOLIGAN FISH (mg/100 g WET WEIGHT)

Site	Preparation method	Calcium	Iron	Zinc
Nass River	Dried	245	1.4	1.5
Bella Coola	Smoked	405	1.8	2.2
Knights Inlet	Raw	273	1.6	1.3
Mean ± SD		308 ± 85	1.6 ± 0.4	1.6 ± 0.4

[a] Composite samples of five fish.

reported previously for samples collected from Bella Coola (mean RE 2100/100 g, range 1650–2920) (Kuhnlein *et al.*, 1982). However, when expressed as per 100 g lipid, vitamin A in ooligan fish, was about 10 times higher than the content of ooligan grease (Table 1). These results suggest that ripening and/or rendering of the ooligan grease resulted in a loss of vitamin A. Drying and smoking also resulted in loss of vitamin A in the fish, but to a lesser extent than was lost in ooligan grease. More vitamin A was lost after drying (about 45%) than smoking (about 30%). Our results suggest *T. pacificus* is a fish high in vitamin A (3200 ± 54 RE/100 g sample). In comparison, fresh sockeye salmon contains 57.8 RE/100 g (Health and Welfare Canada, 1987). Despite loss during preparation, ooligan grease is one of the best sources of vitamin A in natural foods of British Columbia.

Fatty acid profiles of ooligan grease and fish extract are presented in Tables 2a–2d. Fatty acid profiles among grease samples collected from the five different First Nations areas did not vary substantially, nor did the profiles of raw, dried, and smoked fish. However, the fatty acid profile of the ooligan grease was quite different from that of ooligan fish extract. Figure 2 gives a comparison of fatty acid profiles of raw ooligan fish and ooligan grease collected from Knights Inlet. Table 3 shows the fatty

TABLE 5

HEAVY METAL CONCENTRATIONS IN OOLIGAN GREASE (μg/100 g WET WEIGHT)

Site	N	Arsenic	Cadmium	Mercury	Lead
Nass River	5	130 ± 18	1.6 ± 0.2	0.24 ± 0.09	2.2 ± 0.4
Kitimaat	5	150 ± 5	1.3 ± 0.1	0.22 ± 0.05	1.1 ± 0.4
Bella Coola	5	150 ± 11	2.7 ± 0.8	0.28 ± 0.02	7 ± 10.6
Kingcome Inlet	1	125	1.5	0.55	0.5
Knights Inlet	3	130 ± 9	1.6 ± 0.1	0.26 ± 0.02	1.3 ± 0.1
Mean ± SD	19	140 ± 12	1.8 ± 0.5	0.30 ± 0.10	2 ± 2.6
Guideline Level		350[a]	100[b]	50[b]	200[b]

[a] Health Canada for fish meal.
[b] Agriculture Canada for food.

acid concentrations (g/100 g lipid) and their relative abundance (% of total fatty acid extracted) of all grease ($n = 19$) and fish samples ($n = 4$). The most prominent fatty acid in both ooligan grease and fish extract was oleic acid (C18:1), which constituted approximately 41.3 and 53.7% of the total fatty acids identified (Table 3). The second most abundant fatty acid in ooligan grease was docosahexaenoic acid (DHA; C22:6), which constituted approximately 24% of the total fatty acids. In contrast, the second most abundant fatty acid in the fish extract was palmitic acid (C16:0), which constituted about 20% of the total fatty acids. Three fatty acids, linoleic acid (C18:2), eicosaenoic acid (C20:1), and docosahexaenoic acid (C22:6), increased by approximately 100, 440, and 1500%, respectively, during grease preparation. The composition of the other fatty acids decreased during grease preparation by relatively small amounts, ranging from approximately 10% for palmitoleic acid (C16:1) to 73% for eicosapentaenoic acid (EPA). Tables 2a–2d also show the results of fatty acid composition of ooligan fish by different preparations and ooligan grease from different locations.

The results showed differences in total polyunsaturated fatty acids (PUFA) between ooligan grease and fish. The sum of ω-3 and ω-6 in ooligan grease samples was approximately 20 g/100 g lipid, whereas that in extracted fish lipids was approximately 6 g/100 g lipid (Tables 2c and 2d). The higher PUFA in ooligan grease was due to the increased DHA (C22:6), an ω-3 fatty acid. The ratio of polyunsaturated fatty acids to saturated fatty acids changed from 0.2 for fish to approximately 1.0 for grease (Table 2d), and the ratio of ω-3 to ω-6 PUFA changed from 1.7 for fish lipid extract to 16.3 for grease. Overall mean levels of fatty acid categories in ooligan grease were 19 ± 0.91 g/100 g lipid for saturates, 37 ± 3.6 g/100 g lipid for monounsaturates, 19 ± 4.4 g/100 g lipid for ω-3, and 1.2 ± 0.28 for ω-6 (not shown).

The fatty acid results of this study agree with previous analysis (Kuhnlein *et al.*, 1982). However, with better gas chromatography technology at the present time, about 15 to 20 peaks were identified and quantified (Fig. 3). We have identified and quantified levels of octadecatetraenoic acid (C18:4), arachidonic acid (C20:4), EPA (C20:5), and DHA (C22:6). The high levels of DHA (approximately 24% of the total fatty acids identified) in ooligan grease samples suggests that it is an excellent dietary source of DHA or ω-3 PUFA. The nutritional benefits of ω-3 PUFA, including EPA (C20:5) and DHA (C22:6), have been well documented (Leaf and Weber, 1988; Nikkila, 1991; Ruyle *et al.*, 1991; Uauy and Valenzuela, 1992). Our results suggest that a daily intake of 20 g of ooligan grease containing about 3.5 g of DHA and 0.1 g of EPA will adequately supply the minimum quantity of ω-3 fatty acids (2.4 to 3.6 g per day), noted by Nikkila (1991) to reduce blood cholesterol and triglycerides in hyperlipidemic patients and improve general cardiovascular health.

The reason for the relatively high composition of DHA in ooligan grease compared to ooligan fish extract is not known, but may be attributed to microbial conversion of other fatty acids to DHA during the ripening process. Lipase producing microbes were reported in several lipid modification processes, such as interesterification and acidolysis of fat (Okumura *et al.*, 1976; Kalo, 1986; Osada and Hatano, 1992; Osada *et al.*, 1992; Pabai *et al.*, 1994). This interesting phenomenon awaits further study.

Calcium, iron, and zinc, three important minerals in human nutrition, were measured. Since these are not found in significant amounts in fats, only fish composites were analyzed. Depending on the preparation, fish had from 200 to 400 mg of calcium, and 1 to 2 g of iron and zinc per 100 g of fish sample (Table 3). Therefore, eating ooligan fish can make important contributions to human calcium, iron, and zinc daily

needs. In addition, some people eat smoked and dried fish with the bone in, which would increase Ca intake.

Concentrations of arsenic, cadmium, mercury, and lead in ooligan grease are presented in Table 4. Levels of all four heavy metals in grease samples collected from First Nations sites were similar, indicating little point-source contamination. The higher lead level from one area was due to one particular sample, probably from the use of lead-containing equipment in grease processing. Levels of all four heavy metals in ooligan grease were below the guideline levels established by Health Canada (3.5 ppm for arsenic in fish meal) and by Agriculture Canada (1.0, 0.5, and 2.0 ppm for cadmium, mercury, and lead in food) (Table 5).

CONCLUSION

Ooligan grease and ooligan fish are traditional foods of First Nations Peoples of British Columbia, Canada. Both grease and fish are good sources of vitamin A and ω-fatty acids; however, enrichment of ω-3 fatty acids in grease over that in the fish lipids is a particular advantage. Ooligan fish are good sources of Ca, Fe, and Zn; As, Cd, Hg, and Pb are below guideline levels and do not present a health risk.

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