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By-products from gadiform species as raw material for production of marine lipids as ingredients in food or feed

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Abstract

An average production of 10,000 kg cod fillets (gadiform species) will generate by-products with more than 1000 kg marine lipids. More than 30% of these lipids are the health beneficial n-3 fatty acids, which have commercial value. To increase the industrial utilization of these lipids different sources of raw material need to be evaluated in respect to available amounts and chemical composition. The present work presents such data on four gadiform species caught in the Barents Sea (*Gadus morhua* (cod), *Pollachius virens* (saithe), *Melanogrammus aeglefinus* (haddock) and *Brosme brosme* (tusk)) evaluated at three seasons during 1 year. Both seasonal and inter-species differences were found in the amount of by-products and the lipid composition. The levels of polyunsaturated fatty acids were significantly higher in haddock liver and significantly lower in tusk liver compared to saithe and cod. However, regardless of the variations found, the lipids from all samples analysed contained significant quantities of health beneficial fatty acids. Liver was the best lipid source containing between 43 and 69% total lipids. The viscera contained between 2 and 9% lipids and trimmings contained approximately 1% lipids. While the lipids from liver generally contained more than 90% triacylglycerols, the lipids from the other by-products contained higher levels of phospholipids making up more than 60% of the total lipids in muscle and gonads.

Keywords: By-products; Fatty acids; Lipid classes; Cod; Viscera; Liver; Trimmings; Gadiforms

1. Introduction

Globally, more than 130 million tonnes of fish and shellfish are caught each year [1], of this, about 1/4 is discarded. Some of the by-products are utilized, but the main part is dumped to waste. In Norway, about 46% of by-products (viscera, liver and filleting residuals) from the cod fisheries are utilized [2], and only 1/3 of this amount is utilized for human consumption. It is therefore a great potential for the fishing industry to land and utilize a greater part of the total catch for higher value products. A particularly valuable fraction in marine biomass is the marine lipids, which have well documented beneficial health effects [3,4]. These effects are mainly associated with the long chain highly unsaturated fatty acids EPA (20:5 n-3, eicosapentaenoic acid) and DHA (22:6 n-3, docosahexaenoic acid) which are omega-3 fatty acids found in significant quantities in marine lipids. Other valuable lipid components found in marine raw material are phospholipids, lipid soluble vitamins, sterols and colour components. Cod liver oil has been a commercial health care product in Northern Europe for centuries, and cod liver oil as a nutraceutical can be traced back to 1783 [5]. Today, by-products that are utilized for human consumption are mainly liver and roe from relatively large cod (*Gadus morhua*). However, small cod, other gadiform species and fractions of by-products are also potential sources of valuable marine lipids. In order to utilize the marine lipids found in marine by-products, it is necessary to have knowledge about the possible variations in content and composition of the lipids. It is common knowledge that the chemical composition of cod may vary with factors such as age, stage of sexual maturity and diet [6–10] and seasonal differences in proximate and lipid composition in fish are previously suggested to be partly due to differences in water temperature [11,12]. In lean fish species, such as gadiform species, liver is the main lipid depot and the lipid content and composition is shown to vary among seasons [6,7,13]. While the liver lipids consist primarily of triacylglycerols and the muscle lipids consist of phospholipids, the viscera lipids are less explored as commercial products and investigations of the variation in available lipids are needed.

Recently, there has been interest in the processing of cod (*G. morhua*) by-products [15–17] by enzymatic hydrolysis.

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However, previous research on variation in chemical composition of cod by-products is limited and a scientific overview presenting the amounts of the different by-product fractions in different gadiform species are lacking. Some studies have investigated composition of specific fractions of by-products, but in contrast to our present studies, the majority of these studies have not focused on the industrial utilization of these raw materials. To utilize more than the fish fillet for human consumption, data on weight composition of by-products are needed [18]. Some data are established on Fishbase (www.Fishbase.org) for a number of species, however, data on the gadiform species analysed in the present study are generally not currently established in this database. The present data will be valuable for predicting amounts and lipid composition in by-products from various catches of these gadiform species for further processing.

The gadiform species used in the present study were caught in the Barents Sea, in an area with some of the most productive biomasses in the world. Gadiform species make up approximately one-third of the annual catch in these waters [14]. The present study includes seasonal catches of cod (*G. morhua)*, haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and tusk (*Brosme brosme*). By-products were weighed and lipids were analysed enabling calculation of available lipid constituents from the different gadiform species.

2. Materials and methods

2.1. Samples and treatment

In this survey, cod (Atlantic cod; *G. morhua*), haddock (*M. aeglefinus*) and saithe (*P. virens*) were collected from the Barents Sea and tusk (*B. brosme*) was collected from the North Sea. The sample collection started in winter (February/March) in 2001 and was repeated in summer (June) and autumn (September–November) the same year. In order to minimize the influence of size, size requirements were included in the trial. The size was measured as nose to fork of tail and the size specifications were chosen due to common industrial grading of gadiform species (Nordic countries). Only cod was used to study the influence of size. The cod was therefore collected in 3 size groups (50–60, 60–70 and 70–80 cm). The other species had the following size requirements: haddock: 45–55 cm, saithe: 70–80 cm and tusk: 40–50 cm. For each group of fish, a collection of 15 individuals was used. After bleeding, the fish were frozen (ungutted) and stored at <-24 °C until thawing. Before gutting and filleting, the fish was thawed in water with a fish to water ratio 1:4.5. The starting temperature of the water by immersion of the fish was 20 °C. Thawing time was approximately 22 h, to a core temperature of 0 ± 1 °C. After gutting, visceral components, liver, roe, milt, viscera (stomach and gut), trimmings (v-cut and belly flap/nape), heads and backbone were weighed. The filleting parts specified (v-cut, belly flap, head and backbone) were cut corresponding to industrial filleting of gadiform species (BAADER Food Processing Machinery, market leader of fish processing equipment) for whitefish (www.baader.com). The total weight of viscera consisted of all parts except liver. The weight of round fish, length and the weight of head were also determined. The liver, viscera (stomach, gut) and trimmings from each group of fish (a pool from 15 individuals) were homogenized using a Waring Blender with a knife that was sharp enough to cut the hard wall of the stomach. Homogenization of the samples was done within 14 days after catch. The fish were not split in groups according to sex. The aim of this study was to establish a scientific basis for commercial bulk production and the differences between sexes in the material are therefore not important. Another reason for this decision is that separation of the sexes is difficult for immature cod [19].

In addition to the work characterizing saithe described above, one catch (spring/April 2000) of saithe were characterized in more detail studying roe and milt. A collection of 30 kg viscera (all visceral cavity) from saithe were frozen on-board (−20 °C) a freeze trawler before transportation to the laboratory. The samples were thawed before sorting and homogenising the gonads. A characterization of total lipids, lipid classes and fatty acids are described below.

2.2. Lipid analysis

The lipids were extracted using a modified Bligh and Dyer [20] method. Fatty acid methyl esters were prepared according to Metcalfe et al. [21], and analyzed on a Carbo Erba HRGC 5160 gas chromatograph equipped with an Omegawax 320 (Supelco) glass capillary column, employing on-column injection and flame ionization detector. Peaks were reported by a Shimadzu Chrompac C-3R computing integrator, identified by comparison with known standards (Nu-Chek Prep, MN, USA) and quantified by means of the response factor to the internal standard C21:0. Lipid classes were separated by an Iatroscan thin layer chromatography-flame ionization detector system (TLC-FID) (Iatron Laboratories, Tokyo, Japan). Chromarods SIII (Iatron Laboratories, Tokyo, Japan) were first scanned twice through the Iatroscan FID immediately before sample application in order to remove possible contaminants from the rods. Chloroform solutions of the extracts (1 ml, concentration 20 mg/ml) were spotted on the Chromarods SIII by use of a single spotting action and a 10 ml chromatographic syringe. After spotting, the rods were conditioned in a constant humidity chamber for 8 min over a saturated NaCl solution and then transferred immediately to the developing tank. The solvent system consisted of hexane/diethyl ether/formic acid (85:35:0.04).

2.3. Data treatment

Weight of the fractions, the total lipid content, amount of individual fatty acids and lipid classes were evaluated and compared. Multivariate statistical analysis was performed using analysis of effect (ANOVA) and principal component analysis (PCA) in Guideline™ [Camo, Oslo, Norway]. For the weight fractions, results from all individuals in the groups ($N = 15$) were included. Some of the statistical work has been performed using the ANOVA, Tukey's family error rate ($\alpha = 0.05$) in MINITAB. The fatty acids are presented as percentage of total fatty acids, but when appropriate, quantitative values (mg/g lipids) are given. Using percentages is the more common way to present the fatty acid composition and are therefore easier to compare with previous findings.

3. Results and discussion

3.1. Available amounts of by-products

On an average, production of cod fillets will generate 2/3 of the whole body weight as by-products. The present data show that the viscera (all inner fractions) makes up 12–15% of the whole body weight of the four gadiform species analysed, the head 15–20% and the backbone and trimmings make up 18–30% (Table 1). An average daily catch of gadiforms from a trawling vessel (10,000 kg fillets) will generate 17,000–21,000 kg by-products depending on species (Table 2). The commercial value of these by-products is varying, and the present data show significant differences in lipid content and composition in the by-products investigated (Figs. 1 and 2, Tables 3–5). The main lipid depot is found in the liver with the amount of total lipids ranging from 54 to 69% in cod saithe and haddock and 43% in tusk (Table 3). The viscera and trimmings contain lower amount of total lipids (Table 3), ranging from 2 to 9% in viscera and as low as 1% in trimmings. The head, trimmings, backbone and viscera make up more than 60% of the available catch (93%) of the by-products, however, it only