http://journal.nafo.int

J. Northw. Atl. Fish. Sci., Vol. 31: 333–338

Utilization of Deep-sea Sharks at Hatton Bank in the North Atlantic

M. Kjerstad, I. Fossen, H. M. Willemsen
Møre Research, Section of Fisheries
P.O. Box. 5075, N-6021 Ålesund, Norway

Abstract

The study describes the relative yield of consumption- and by-products from five deep-water sharks frequently caught in the fishery along the continental slopes of the north-eastern Atlantic Ocean. The species described are: leafscale gulper shark (*Centrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*), black dogfish (*Centroscyllium fabricii*), longnose velvet dogfish (*Centroscymnus crepidater*) and birdbeak dogfish (*Deania calcea*).

It is possible to utilize backs, fillets, belly flaps and tails as consumption products. Due to differences in the size of the species, it is most convenient to produce consumption products of the largest species, such as leafscale gulper shark and Portuguese dogfish. Backs and fillets from leafscale gulper shark gave the highest relative yield, 26.1% and 20.6% of round weight, respectively. The belly flaps of the five species constitute 10% to 15.8% of the body weight. Liver is the most demanded by-product due to high oil, particularly squalene, content. The yield of liver varied from 18.3% to 26.2% of round weight. Leafscale gulper shark had the highest average squalene content in liver oil of 65.5%. The findings indicate a potential for increased utilization for both consumption and by-products from deep-sea sharks.

Key words: by-products, consumption product, deep-sea sharks, Hatton Bank, North Atlantic dogfish, shark liver oil, squalene, utilization

Introduction

An increased commercial interest in deepwater species has developed in several European countries (Gordon *et al.,* 2003). This is partly a result of reduced availability of the more traditional commercial species (Merrett and Haedrich, 1997), and the need for alternative resources to maintain profit. Around Rockall, Reykjanes Ridge, Mid Atlantic Ridge, East Greenland and other areas, fishermen have begun targeting different deep-sea species. In addition to more familiar species, new focus has been put on additional fish species taken as by-catch, such as sharks, rays and *Mora mora*.

Since 1998 Norwegian trawlers and longliners have carried out trial and commercial fisheries in the Hatton Bank area (ICES VIb and XII) at depths between 600–2 000 m. In the deepwater fishery at Hatton Bank a number of species are caught, reflecting the high diversity of fish species found at such depths (Gordon, 2001). Norwegian trial fisheries have revealed about 40 different species, of which 15 were *Chondrichthyes* from the order *Squaliformes* (Langedal and Hareide, MS 1998; MS 1999). About 75% of the longline catches in weight are composed of sharks, whereas trawl catches never consisted of more than 17% sharks by weight (Langedal and Hareide, MS 1998; MS 1999).

The total global catch of sharks, rays and *Chimaera* spp. was 828 364 tons in 2000 (FAO, 2002). All over the world shark are caught both in directed fisheries and as by-catch in other fisheries. The value of different shark species depends on their products and they can vary from very expensive to products of very low commercial value. Over the last several decades, piked dogfish (*Squalus acanthias*) has been one of the most popular sharks in the European market, but in the Atlantic the piked dogfish stock is seriously depleted (Vannucci, 1999). This has lead to an increasing interest in utilizing other deep-sea sharks for consumption.

The most common consumption products from sharks are backs, fillets and steaks. Shark tails and fins are popular products in Chinese cuisine. Belly flaps are also utilized and are for some species regarded as high value products, such as the "Schillerlocken" from piked dogfish.

Liver is among the most important commercial by-product from shark species due to its high oil content, particularly squalene. Deep-sea sharks have generally higher squalene content in the liver than sharks found in shallower waters (Nunes *et al.,* 1989). Squalene is usually hydrogenated to squalane, which is a more stable compound used by the cosmetic industry. Other interesting components found in shark liver are the antimicrobial and antiangiongenic sterol, squalamine (Moore *et al*., 1993; Williams *et al.,* 2001), and the components having wound healing properties and protection from radiation damage, such as diacylglycerol ethers (Borch-Jensen *et al*., 1997; Pugliese *et al*., 1998). Shark cartilage is claimed to protect against cancer and it is found to protect against reactive oxygen species (Felzenszwalb *et al*., 1998).

To minimize discards and increase profitability of the deep-water fishery it is important to utilize as many species and products as possible. The aim of the study is to describe the potential for utilization and the relative yield (portion of round fish) of different products from leafscale gulper shark (C*entrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*), black dogfish (*Centroscyllium fabricii*), longnose velvet dogfish (*Centroscymnus crepidater*) and birdbeak dogfish (*Deania calcea).*

Materials and Methods

Material was collected during a Norwegian exploratory longline fishery at Hatton Bank in 1999. Samples were taken at random from stations located on the west side of the bank at depths between 1 000 and 1 600 m. All stations were located within the coordinates 58°40' and 59°40'N and 14°50' and 19°10'W.

Yield measurements of all species were taken at sea in 1999. All yield measurements were taken relative to the shark round weight. Ten specimens of each species were used to measure yield of products and body parts. Head, gut, fins and belly flaps were cut off the fresh shark before the fillets and backs were produced by hand. A Steen skinning machine removed the skin from the fillets and backs.

Specimen of leafscale gulper shark, Portuguese dogfish and black dogfish were also frozen whole and yield measurements of by-products were taken in the laboratory. Five specimens of each of the three species were used in the yield measurements of pancreas, spleen, rectal gland, heart, stomach, intestine, oviduct, egg and cartilage. Stomach and intestines were cleaned before weighing.

Liver samples from ten specimens from each of the five species were frozen at sea and kept at -30°C. In the laboratory the livers were thawed and homogenized in a blender. After being homogenized, the preparate was left at room temperature until the oil floated to the top of the homogenates. The oil was then heated to 70°C and filtered. The shark liver oil was frozen and kept at -20°C until analyzed. Squalene content in shark liver oil was analysed by gas capillary chromatography, using squalene and squalane as standards.

Total cartilage yield was measured from 5 specimens of leafscale gulper shark. Each shark was weighed round and chopped into pieces and boiled in freshwater (1:1) for about 80 minutes. Most of the meat was removed from the cartilage before boiling. The cartilage pieces were sorted and cleaned in water after boiling. The cartilage was dried in a fume hood for 24 hours at 60°C before being weighed individually.

Market tests and trial productions were carried out in cooperation with a Norwegian longliner and three fish exporters.

Results and Discussion

The size of the shark is decisive for its utilization potential. In general, leafscale gulper shark and Portuguese dogfish were larger than black dogfish, longnose velvet dogfish and birdbeak dogfish (Table 1).

Consumption products

Yield measurements (as portion of round weight) of body parts and consumption products varied both within and between species (Table 2). Yield measurements of "gutted head on" indicates some differences between the species with regards to how much the internal organs contribute to the overall weight and to some degree the species' body form (Table 2). Significant differences in the yield of skinless backs and skinless fillets were found between species ($F_{3,\ 40}$ = 7.23, $p<0.001$ and $F_{(3,\ 40)} = 9.295$; $p<0.001$). Differences were due to larger relative yield of skinless backs of leafscale gulper shark compared to all species except birdbeak dogfish, which were not included in the analysis ($p<0.03$, Bonferroni pairwise comparison (BPC)). Differences were probably a result of the more slender body of leafscale gulper shark.

TABLE 1. Total length and weight range of individuals of the different deep-sea shark species used in yield measurements for body parts. Average values are given in parentheses.

Species	Total length (cm)	Total weight (kg)
Leafscale gulper shark	89.5–115.5 (101.0)	3.76–8.53 (5.61)
Portuguese dogfish	90.0–113.5 (107.2)	5.14–10.40 (8.90)
Black dogfish	69.0–84.5 (74.6)	1.64–3.79 (2.35)
Longnose velvet dogfish	74.0–86.0 (81.2)	1.87–2.88 (2.45)
Birdbeak dogfish	75.0–98.5 (86.6)	1.65–3.91 (2.55)

TABLE 2. Yield measurement (% of round weight) of products and body parts of five deep-water sharks (± SD).

Products	Leafscale gulper shark	Portuguese Dogfish	Black dogfish	Longnose velvet dogfish	Birdbeak dogfish
Gutted head on	75.9 (2.5)	63.4 (3.3)	68.5 (4.6)	73.5 (2.2)	75.7 (1.0)
Skinless back	26.1 (2.5)	22.9 (1.4)	23.5 (2.8)	23.1 (1.9)	31.5 *
Skinless fillet	20.6 (2.3)	17.6 (2.2)	16.1 (2.5)	14.9 (3.2)	–
Head	25.2 (2.0)	19.2 (2.1)	26.9 (2.2)	24.8 (2.2)	21.4 (1.9)
Belly flaps	15.8 (1.4)	15.3 (0.9)	10.0 (0.7)	16.2 (1.5)	14.3 (1.5)
Tail	1.7 (0.1)	1.5 (0.2)	1.5 (0.3)	1.8 (0.2)	1.6 (0.2)
Fins	3.8 (0.3)	2.0 (0.4)	3.4 (0.5)	4.0 (0.4)	5.4 (0.8)
Liver	18.3 (1.3)	26.2 (2.6)	20.6 (3.3)	19.9 (2.1)	20.8 (0.8)
Remaining organs	6.2 (4.1)	8.3 (1.5)	8.8 (6.6)	4.5 (1.0)	3.1 (0.7)

* Data from one specimen only

The yield of skinless fillet varied from 14.9% to 20.6%, compared to cod having approximated 30–36% yield of fillet. This is a result of large amount of internal organs, especially the liver, which by itself represents a yield between 18.3% and 26.2% of round weight.

Differences between species were also found when comparing the relative yield of belly flaps ($F_{4, 50}$ = 41.8, p<0.001) where the yield from black dogfish was significantly lower than all the other species (p<0.001, BPC). The belly flaps from both black dogfish and birdbeak dogfish were thinner than for the other species, which contributed to the lower relative yield from these species.

The average yield of fins and tails from the five species were respectively 3.7% and 1.6% of round weight. Godievskaya (1973) found that fins from shark species located in shallower water were 5.3% of round weight. This is in accordance with our results. While the tail made up a similar proportion of body weight, the variation, with respect to fins, was somewhat larger both between and within species. The price level for shark fins depends on the yield of fin needles and their size, texture and appearance. Market tests indicated difficulties in finding markets for the fins of the deep-sea sharks. This is due to the low content of fin needles. However, the Asian market buys tails of deep-sea sharks.

A market has developed for several products from deep-sea sharks. Backs of leafscale gulper shark and Portuguese dogfish are most popular, due to the large size. Market tests have shown that the small shark species usually have been sold as fillets. In cooperation with a smokehouse in Germany, a trial production of smoked belly flaps from leafscale gulper shark, Portuguese dogfish, black dogfish and longnose velvet dogfish was carried out (Fjørtoft and Kjerstad, 2001). Belly flaps from these species differed from those of piked dogfish with respect to consistency, fat and water content, and in having a whitish brown color to the surface membrane. The belly flaps from these deep-sea species were not suited as a substitute for smoked belly flaps from piked dogfish. To establish a market for belly flaps from deep-sea species it would be necessary to introduce them as new products, not substitutes.

By-products

The yield of liver showed significant differences among the species ($F_{4, 47}$ = 32.36, *p*<0.001). The differences were due to a relatively larger liver among Portuguese dogfish compared to the other species (*p*<0.001, BPC). Large variations in yield of liver were also observed within the species. This was also found in other studies (Peyronell, *et al*., 1984; Batista and Nunes, 1992). The total oil content was not measured in this study, but Borch-Jensen *et al*. (1997) showed that Portuguese dogfish and leafscale gulper shark have respectively 77.6% and 77.2% oil in the liver.

Significant statistical differences were found in the content of squalene in the liver oil among the different species ($F_{4, 47}$ = 32.36, *p*<0.001) (Fig. 1). Differences were due to less squalene in the liver oil from black dogfish compared to all other species ($F_{4, 47}$ = 32.36, *p*<0.001). The squalene content from leafscale gulper shark was also higher than for Portuguese dogfish (*p*<0.01, BPC). Due to the high squalene contents, liver from leafscale gulper shark has the highest price level among the deep-sea sharks analyzed.

The squalene content in liver oil of leafscale gulper shark varied between 38.9% and 83.7%. This kind of variation was also seen in other areas (Hernández-Pérez *et al.*, 1997).The squalene variation is not fully explained, but it is claimed that size, sex, age and fishing ground could affect the squalene content (Peyronell *et al*., 1984; Hernández-Pérez *et al.*, 1997; Kreuzer and Ahmed, 1978). The large variation in squalene contents within and between species combined with relatively low number of observations makes a detailed comparison with other studies difficult.

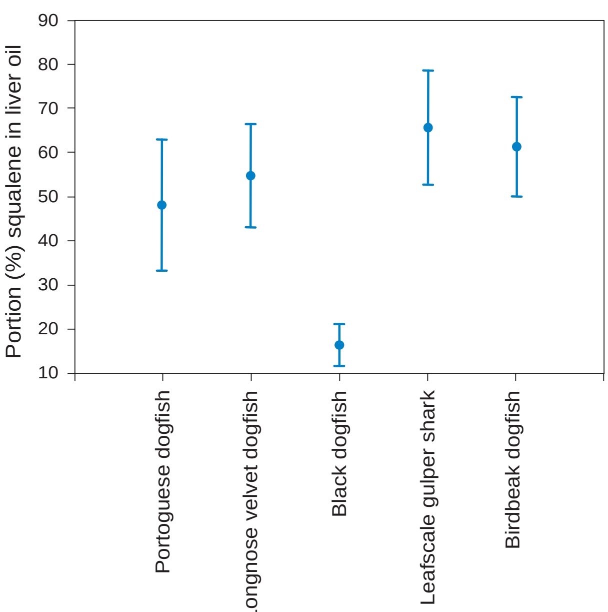

Fig. 1. Average squalene content (%) in liver oil from five deep-sea sharks (± SD).

The results indicate some variations between species in yield measurements of the internal organs (Table 3). However, in general, the internal organs other than the liver represent a small relative yield. These other organs, however, yield an interesting array of substances used for cosmetic and medical purpose (Borch-Jensen *et al*., 1997; Moore *et al*., 1993; Subasinghe, 1998; Summers and Wong, 1992).

The dried cartilage yield of leafscale gulper shark was found to be 1.4% of the round weight. Components of interest in shark cartilage are glucosamine and chondroitin that can be used in treating osteoarthritis (Felson and McAlindon, 2000; McAlindon *et al*., 2000). The cosmetic industry is also interesting in chondroitin sulphate, especially for its ability to bind large amounts of water (Subasinghe, 1998).

Further perspective

Only a few studies have focused on the possibilities of utilizing the entire body weight of deep-sea shark. Our work therefore represents a pilot study. Potentially, it is possible to utilize 100% of the shark. Utilization of backs, belly flaps, liver, and tails would represent a yield between 55% and 68% of the average body weight of the species examined. If we also utilize heads in producing cartilage, chondroitin and glucosamine, we could utilize 82% to 89% of the total body weight. The potential of utilization of other entrails are more uncertain, but the interest for shark by-products in the cosmetic and pharmaceutical industry is increasing. New substances could be found in search of “bioactive compounds” in medical and pharmaceutical purposes, which may constitute a potential for increased utilization of entrails in the future.

Deep-sea species are more difficult to handle and process than most fish because of their difference in anatomy (MàcNamara, 1996). Sharks would therefore need different handling arrangements if caught in quantities. An efficient production line is therefore of

TABLE 3. Average yield (% of round weight) of some internal organs of five individuals of leafscale gulper shark, Portuguese dogfish and black dogfish (± SD).

By-products	Leafscale gulper shark	Portuguese dogfish	Black dogfish
Pancreas	0.18 (0.04)	0.21 (0.03)	0.28 (0.09)
Spleen	0.08 (0.02)	0.20 (0.09)	0.22 (0.12)
Rectal gland	0.03 (0.01)	0.02 (0.01)	0.04 (< 0.01)
Heart	0.09 (0.01)	0.08 (0.02)	0.08 (0.02)
Stomach	2.43 (0.38)	2.85 (0.86)	2.63 (0.37)
Intestine	0.61 (0.08)	2.64 (0.52)	1.67 (0.29)
Oviduct	0.87 (1.04) *	0.56 (0.35)	0.67 (0.31)
Egg	0.55 (0.36) **	0.83 (0.43)	5.50 (4.22)

* $n = 3$, ** $n = 2$

vital importance for the fishers interested in spending time on processing such by-catches. During the exploratory fishery different processing equipment were tested. After some adjustments both mechanical skinning and filleting of shark backs was successful, except for birdbeak dogfish, where skinning failed due to the texture of the skin.

Commercial utilization of the deep-sea resources has raised concern due to the longevity, low fecundity and low production of these species in general (Merrett and Haedrich, 1997). This is an important issue and it is doubtful that such stocks will sustain direct exploitation from a larger fleet. However, many of these species can be found in large areas and are likely to sustain a more limited by-catch fishery.

It is difficult to estimate the potential in quantities with respect to consumption- and by-products of deep-sea sharks. Much of the fundamental information is lacking. There is insufficient knowledge about biological aspects, stock sizes, catches and landings of these species. One problem is that catches are recorded by species groups rather than as individual species (Bergstad *et al.*, MS 2001). An additional concern is that reporting and information on the level of discarding of catches are poor. Most of the by-catches of the smaller species are not landed at all. Thus the liver of all species could be utilized to increase utilization of these sharks. The by-catch mortality in deep-sea fishery is high (Merrett and Haedrich, 1997) and this constitutes an unaccounted mortality. From an environmental and economical point of view it is therefore important to utilize all shark species that occur in the catches, rather than throwing them overboard.

To optimise utilization of this recourse it is important to take into consideration both the biological and economical aspects. During the 1980s and 1990s there was a dramatic increase in the exploitation of deep-water species in the Northeast Atlantic (Connolly and Kelly, 1996). It is therefore important that the scientific community gets involved in gaining as much information as possible at an early phase of the fishery. In the future it will be important to combine the biological data from surveys with the perspective of commercial utilization of deep-sea sharks. This study has shown that consumption- and by-products from deep-sea sharks may have the potential for further development.

Acknowledgements

Thanks to the company Norwegian Oils for chemical analyses of shark liver oils, the crew onboard the longliner "*Loran*", for help during sampling and production of the sharks, to the staff at Møre Research for close collaborations and interesting discussions. Thanks to the Norwegian Research Council, The Norwegian Industrial and Regional Development Fund and The Norwegian Directorate for Fishery for funding the project.

References

BATISTA, I., and M. L. NUNES. 1992. Characterization of liver oils. *Fish. Res.*, **14**: 329–334.

BERGSTAD, O. A., J. D. M. GORDON, and P. LARGE. MS 2001. Is time running out for deep-sea fish? *ICES Newsletter*, **38**: 18–19.

BORCH-JENSEN, C., M. P MAGNUSSEN and J. MOLLERUP. 1997. Capillary supercritical fluid chromatographic analysis of shark liver oils. *JAOCS*, **74**(5): 497–503.

CONNOLLY, P. L., and C. J. KELLY. 1996. Catch and discards from experimental trawl and longline fishing in the deep water of the Rockall Trough. *J. Fish Biol*., **49**: 132–144.

FAO (Food and Agricultural Organization of the United Nations). 2002. Fishstat Plus Version 2.30 by Yuri Shatz. (Dataset total production 1950–2000, selection: sharks, rays and chimeras). (See also, *http://apps.fao.org/page/collections?subset=fisheries*).

FELZENSZWALB, I., J. C. PELIELO DE MATTOS, M. BERNARDO-FILHO, and A. CALDEIRA-DE-ARAÙJO. 1998. Shark cartilage-containing preparations: Protections against reactive oxygen species. *Food Chem. Toxicol*., **36**: 1079–1084.

FELSON, D. T., and T. E. MCALINDON. 2000. Yield measurements, chemical analysis and screening of biological activity and market test need to be carried out for different products in the future, to identify compounds for food, chemical and medical industries. Glucosamine and chondroitin for osteoarthritis: To recommend or not to recommend. *Arthrit. Care Res*., **13**(4): 179–182.

FJØRTOFT, K. L., and M. KJERSTAD. MS 2001. Marknadsutvikling for djuphavsartar i samband med Hatton bank toktet i 1999. Report from market test of deep sea species. *Møre Research*, 44 p.

GORDIEVSKAYA, V. S. 1973. Shark flesh in the food industry. Pacific Scientific Research Institute of Marine Research and Oceanography (translated from Russian), published for the National Marine Fisheries Service, NOAA, by the Israel Program for Scientific Translations, Jerusalem, 26 p.

GORDON, J. D. M. MS 2001. Deep-water fisheries at the Atlantic Frontier. *Cont. Shelf Res.*, **21**: 987–1003.

GORDON, J. D. M., O. A. BERGSTAD, I. FIGUEIREDO, and G. MENEZES. 2003. The deep-water fisheries of the Northeast Atlantic: I. description and current trends. *J Northw. Atl. Fish. Sci.*, **31**: 137–150 (this volume).

HERNÁNDEZ-PÉREZ, M., R. M. M. GALLEGO, P. J. P. ALAYÓN, and A. B. HERNÁNDEZ. 1997. Squalene content in livers from deep-sea sharks caught in Canary Islands water. *Mar. Freshwater Res.*, **48**: 573–576.

KREUTZER, R., and R. AHMED, 1978. Shark utilization and marketing. Food and Agriculture Organization of the United Nations, Rome, 180 p.

LANGEDAL, G., and N. R. HAREIDE. MS 1998. Rapport fra forsøksfiske på Hatton bank med M/S Koralnes. Fiskeridirektoratet. Report from exploratory trawl fishery at Hatton Bank. The Norwegian Directorate for Fishery, 33 p.

LANGEDAL, G., and N. R. HAREIDE. MS 1999. Rapport fra forsøksfiske med line på Hatton bank med M/S Loran. Fiskeridirektoratet. Report from exploratory longline fishery at Hatton Bank. The Norwegian Directorate for Fishery, 54 p.

MÀCNAMARA, J. P., 1996. The handling, processing, storage and eating qualities of deep water fish. The sea fish industry Authority. *Seafish Report*, No.SR453, 27 p.

McALINDON, T. E., M. P LA VALLEY, J. P. GULIN, and D. T. FELSON. 2000. Glucosamine and chondroitin for treatment of osteoarthritis. *JAMA*, **283**(No.11): 1469–1483.

MERRETT, N. R., and L. HAEDRICH, 1997. Deep-sea demersal fish and fisheries. Chapman & Hall, London, 231 p.

MOORE, K. S., S. WEHRLI, H. RODER, M. ROGERS, J. N FORREST, D. MCCRIMMON, and M. ZASLOFF, 1993. Squalamine: An aminosterol antibiotic from the shark. *Proc. Natl. Acad. Sci. USA*, **90**: 1354–1358.

NUNES, J., I. BATISTA, R. E. CAMPOS, and A. VIEGAS. 1989. Aproveitamento e valorizaccào de algumas espècies de tubarào. *Relat. Tèc. Cient. INIP*, Lisboa (7), Jun., 38 p.

PEYRONELL, D., J.ARTAUD, M. C. IATRIDES, P. RANCUREL, and J. L. CHEVALIER. 1984. Fatty acid and squalene compositions of Mediterranean *Centrophorus* spp. egg and liver oil in relation to age. *Lipids*, **19**(9): 643–648.

PUGLIESE, P. T., K. JORDAN, H. CEDERBERG, and J. BROHULT. 1998. Some biological actions of Alkylglycerol from shark liver oil. *J. Altern. Complem. Med*., **4**(1): 87–99.

SUMMERS, G., and R. WONG. 1992.Cosmetic products from semi-refined shark liver oil. *INFOFISH Internatl*., **2**: 55–58.

SUSBASINGHE, S. 1998. Shark products – for health and beauty. *INFOFISH Internatl*., **4**: 49–55.

VANNUCCINI, S. 1999. Shark utilization, marketing and trade. FAO, Rome, 470 p.

WILLIAMS, J. I., S. WEITMAN, C. M GONZALES, C. H JUNDT, J. MARTY, S. D. STRINGER, K. J. HOLROYD, M. P. MCLANE, Q. CHEN, M. ZASLOFF, and D. D. VON HOFF. 2001. Squalamine treatment of human tumors in nu/nu mice enchases platinum-based chemotherapies. *Clin. Cancer Res*., **7**: 724–733.