Comparative study on the liver fatty acid profiles of the red toothed trigger fish (*Odonus niger*) from southwest coast of India

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Abstract

In order to find an alternative source for the highly unsaturated fatty acids oil with lower cost, a marine trash fish *Odonus niger* has been analysed and characterised. The body weight and the corresponding liver weight of the fish were studied and the results showed that for one gram increase in the size of the animal, the liver weight can increase to 0.04 g. The oil yielding capacity of the liver was assessed by four different methods namely Soxhlet, Bligh and Dyer, Direct steaming and Solar extraction. The percentage of oil yield was high in Soxhlet method (67.7%), but it was 54.3% in Bligh and Dyer method, 42.5% in direct steaming method and minimum of 32.0% in solar extraction method. The solidification point of all the extracted oils remained at 29 ± 0.5°C. The specific gravity (0.95 to 0.96) and refractive index (1.42μ to 1.48μ) of the oil extracted by the four different methods were not varied significantly. The cholesterol contents of the oil extracted by Bligh and Dyer and direct steaming extraction methods were at the highest level (1991.00 and 2059.00mg $100ml^{-1}$) but it was 50% less in other methods. The percentages of PUFA in the total fatty acid of the oils were 13.78, 20.46, 19.07 and 22.54% (by weight) in solar extraction, direct steaming, Soxhlet and Bligh and Dyer methods, respectively. Thus the physico-chemical properties of liver oil of *O. niger* were found to be influenced by the extraction adopted methods. Also it is clear that Bligh & Dyer method is the suitable method for the extraction of liver oil from marine fishes without much loss of nutrients.

Keywords: *Odonus niger*, PUFA, FFA, Soxhlet, Bligh and Dyer, Direct steaming, Solar extraction

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Introduction

Among the fishes of the world, the family Balistidae constitutes a substantial fishing in certain areas during particular months in a year (Immanuel *et al*., 2000). Among them *Odonus niger* (Ruppel), is a demersal fish, which occurs in enormous shoals and form regular fishery in the south west coast of India (Immanuel *et al*., 2000, 2009) and obtained in large quantities in trawling during monsoon season as well as in other months. This species is commonly treated as trash fish and used for poultry feed along with huge quantity of livers (Immanuel *et al*., 2000).

In fishery industries, the value added fishery products such as fats and oils are extracted from whole body or liver of several fish species. Various authors have studied the extraction methods of oil from body and livers of fishes and analysed the physical and chemical properties, e.g., shark liver oil (Shenoy & Dey, 1984; Davidson & Cliff, 2002) and dogfish liver oil (Sunarya *et al*., 1992); rays liver oils (Garcia *et al*., 2004) and teleost fish species liver oil (Zheng *et al*., 2004). The fish oils and marine animal oils are characterized by a large group of fatty acids. These fatty acids can be classified as saturated, mono-unsaturated and polyunsaturated groups. Moreover these oils are having rich source of energy and vitamin A and D (Nair & Gopakumar, 1985; Rossell, 1986; Adrianus, 1993; Aidos *et al*., 2002; Adebiyi and Bawa, 2006; Immanuel *et al*., 2009).

Liver oil of different sources will have various physical and chemical properties. Sunarya *et al.* (1992) reported that very small amount of cholesterol, which is the un-saponifiable fraction of oil present in the liver oil of dogfish. Iwasaki and Harada (1984) reported that the blue shark liver tissues contain large quantity of cholesterol.

Adopted methods for isolation of fats have significant influence on its composition. Sunarya *et al.* (1992) reported signify-cant changes in fatty acid profile as well as cholesterol percentage of dogfish liver oil extracted by different methods (i.e., direct steaming, Soxhlet, Bligh and Dyer methods). Literature pertained to the above is still wanted as for *O. niger* is concern. Therefore the present study was under taken to find out the liver index, suitable methods for liver oil extraction and physicochemical characterization of oil.

Materials and methods

A total of 500 specimens (*O. niger*) were randomly collected from the landing centres of Kanyakumari District, Southwest coast of India in different fishing seasons (From June to November, 2004). The length (cm, total length) and weight (g, fresh weight) of each specimen was measured. The length-weight pairs were plotted in order to find their growth. The parameters and related statistics of the log transformed LWR ($\log W = \log a + b \log L$;

Where W = weight of fish in grams, L= total length of fish in centimeters, a=constant of proportionality, b=allometry coefficient) were obtained via ordinary least square regression. Then the abdomen of each specimen was

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dissected and the liver was carefully removed and weighed separately using an electrical monopan balance (accuracy ± 0.1 g). The weight of the fish and the liver were related using the hepatosomatic index (HSI) formula.

$$HSI\ (\%) = \frac{\text{Weight of liver (g)}}{\text{Weight of fish (g)}} \times 100$$

Liver of *O. niger* were weighed and chilled in ice and packed in air tight containers prior to arrival in the laboratory. They were in good condition and did not show any visual trace of spoilage. In the laboratory, the ice cubes were discarded and all the unwanted materials such as blood vessels and visceral materials were removed, cleaned well and were stored at -20^{O}C in a deep freezer until use.

Four different methods were adopted for the extraction of oil from the liver.

i) Solvent Extraction (Soxhlet) method (Folch *et al.,* 1957)
ii) Bligh and Dyer method (Bligh & Dyer, 1959)
iii) Direct steaming method (Sunarya *et al*., 1992)
iv) Solar extraction method (crude method)

Solar extraction method was standardized in our laboratory after being thawed the livers at ambient temperature. The livers were weighed and placed in a glass bowl, exposed under hot sunlight (35±2^{O}C). Within 15 min. the oil started to melt and at every 30 min intervals the melted oil has been collected in a well-cleaned glass beaker and within 4 to 5 hours, the complete oil was separated. The percentage of oil yield was calculated as:

$$\text{Yield of oil} = \frac{\text{Weight of the extracted oil (g)}}{\text{Weight of the liver (g)}} \times 100$$

Similarly all the oil extracted by the three methods was quantified.

After extraction, the oils were kept in separate containers in freezer (-20^{O}C) until further use. The physical properties such as solidification point, specific gravity and refractive index of the different extracted oils were analysed by the method of Narasimhan *et al*. (1965) and AOCS (1998). The cholesterol content was estimated by the method of AOCS (1998).

Fatty acid methyl esters (FAMEs) of oil samples were prepared according to the AOCS (1998) official method Ce 1b-89 and analyzed with regard to the amount of individual fatty acids. The different FAMEs were separated from each other with gas chromatography (GC) (Miller & Berger, 1985).

The results obtained were analysed through one-way ANOVA and linear regression tests followed by Zar (1974).

Results

The harvested fish samples were measured 13.0cm length and the largest one was 22.5cm length. The corresponding weight was also varied from 45.0 to 120.0g (Table 1). The length-weight data obtained for the 500 fish were plotted and obtained a linear trend relationship (Fig. 1). Linear regression statistics computed ($\log W = 0.0296 + 2.966 \log L$) was correlated ($r^2 = 0.9727$) and significant ($P<0.001$). The liver weight of

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the smallest fish was 4.0g and increased to 7.40g in the largest fish sampled. The relation between the body weight and the liver weight was highly significant (P<0.001), indicating that increasing by gram caused the animal size and the liver weight increase (Table 1).

The percentage of oil yielded from the fish liver in different extraction methods were given in Figure 2. Among the tested methods, the difference between the percentage of oil yielded (67.7±0.68%) in Soxhlet extraction method and the former was significantly higher (P<0.001) than that in other methods. In Bligh and Dyer and direct steaming methods, the percentage of oil yield recorded were 54.3±0.66 and 42.5± 0.40%, respectively. In solar extraction method the lowest yield of 32.0±0.91% oil was registered.

The physico-chemical properties of the oils extracted by the different methods were given in Table 2. Irrespective of the different methods followed for the extraction of oil, the solidification point remained at 29.0±0.5°C. The specific gravity of the oils extracted by four different methods were 0.9581, 0.9519, 0.9523 and 0.9525 in Soxhlet, Bligh and Dyer, direct steaming and solar extraction methods, respectively. The refractive index at 29°C was also almost similar in all the four methods; they were 1.426, 1.466, 1.483 and 1.477µ in Soxhlet, Bligh and Dyer, direct steaming and solar extraction methods, respectively. The cholesterol content of the oil extracted by Bligh and Dyer and direct steaming extraction methods was at higher level (1991mg and 2059mg ×100ml^{-1}). In the other two methods, the content of cholesterol was reduced.

Table 1: Length and weight relationship of trash fish *O. niger* and its liver index (n = 500)

Length of fish (cm)	No. of fish (n = 500)	Body weight range (g)	Mean body weight (g)	Liver weight range (g)	Mean liver weight (g)	Liver index (%)
12.5 - 13.5	26	45 - 47	45.75±0.82	4.0 - 4.5	4.12±0.21	9.15
13.5 - 14.5	48	46 - 50	48.60±1.85	4.0 - 4.5	4.30±0.24	8.84
14.5 - 15.5	73	50 - 57	53.93±2.20	4.5 - 5.0	4.76±0.35	8.45
15.5 - 16.5	52	57 - 65	61.00±2.79	5.0 - 5.5	5.15± 0.22	8.44
16.5 - 17.5	89	70 - 77	74.11±1.85	5.0 - 5.5	5.41±0.18	7.29
17.5 - 18.5	104	80 - 87	83.57±2.27	5.5 - 6.0	5.88±0.26	7.03
18.5 - 19.5	57	87 - 93	90.00±1.63	6.0 - 6.5	6.16±0.23	6.85
19.5 - 20.5	23	98 -104	100.00±2.44	6.5 - 7.0	6.70±0.26	6.70
20.5 - 21.5	16	108 -114	110.66±2.49	7.0 - 7.5	7.30±0.24	6.59
21.5 - 22.5	12	118 -120	119.00±1.00	7.0 - 7.5	7.40±0.10	6.21

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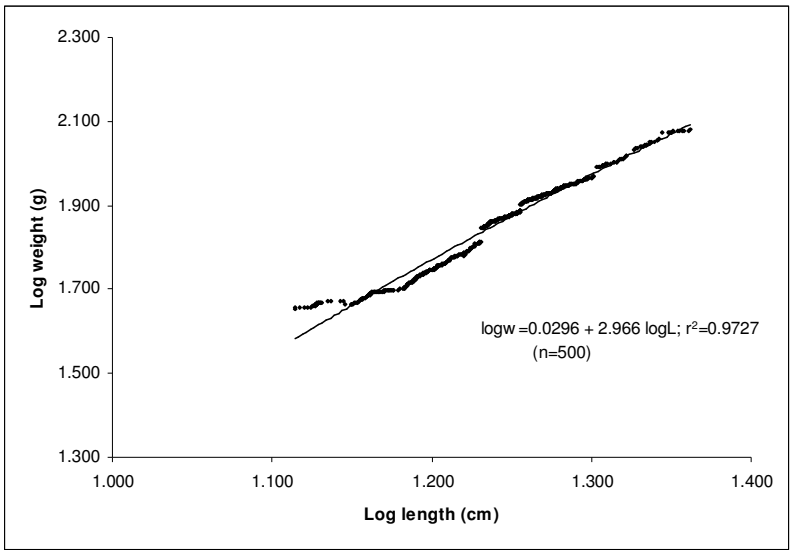


Figure 1: The relationship between the total length (cm) and body weight (g) of trash fish (*O. niger)* in the present study

Table 2: Physical and chemical composition of extracted liver oil in *O. niger* with different methods

Parameters	Soxhlet Extraction	Bligh &Dyer Extraction	Steaming Extraction	Solar Extraction
Solidification point (°C)	29±0.5	29±0.5	29±0.5	29±0.5
Specific Gravity	0.9581	0.9519	0.9523	0.9525
Refractive Index (μ) (at 29°C)	1.426	1.466	1.483	1.477
Cholesterol (mg $100ml^{-1}$)	1159±7.34	1991±3.55	2059±6.53	1091±5.71

Each value is a mean (± SD) of three replicate samples

The details of the fatty acid profile of the trash fish liver oil extracted by different methods were given in Table 3. The most abundant fatty acid in the *O. niger* liver oil was C16: 0 (Palmitic acid), i.e., 21.70% in Soxlet method, 18.50% in Bligh and Dyer method, 19.26 % in direct steaming method, and 24.60% in solar extraction method.

The fatty acid level showed that the saturated fatty acid Methyl esters (Fame) in the different methods of extracted oils were, 52.73, 47.05, 49.05 and 59.54 % in Soxhlet, Bligh and Dyer, direct steaming and solar extraction methods, respectively. The mono unsaturated fatty acid percentage in the oil extracted by solar extraction method was lower (26.68%), more or less same percentage in the oils of direct steaming and Bligh and Dyer methods (30.49 and 30.41%). In Soxhlet method, it was 28.20%.

The detected polyunsaturated fatty acids (PUFA) in the fame were minimum of 13.78% in solar extraction method and maximum of 22.54 % in Bligh and Dyer method. Soxhlet and direct steaming extraction methods have more or less same percentage of PUFA (19.07% and 20.46 %).

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Table 3: Fatty acid composition (% - by weight) in liver oil extracted by different methods in the present study

Carbon No.	Soxlet extraction	Blig & Dyer extraction	Steaming extraction	Solar extraction	Summary of One-way ANOVA
C 9 : 0	nd *	0.39	0.004	nd	S (F = 1460.036)
C10 : 0	0.86	1.43	1.21	nd	S (F = 132.213)
C11 : 0	2.43	1.14	1.32	2.62	S (F = 14626.063)
C12 : 0	0.83	nd	0.65	0.30	S (F = 726.333)
C13 : 0	1.00	1.16	0.96	1.21	S (F = 65.296)
C14 : 0	4.86	2.05	4.39	5.92	S (F = 2179.184)
C15 : 0	2.82	2.06	2.65	2.60	S (F = 160.082)
C16 : 0	21.70	18.50	19.26	24.60	S (F = 757.556)
C17 : 0	1.74	1.03	1.53	4.07	S (F = 730.676)
C18 : 0	13.96	14.70	14.23	15.88	S (F = 288.090)
C19 : 0	nd	nd	nd	nd	–
C20 : 0	1.78	2.42	1.76	1.45	S (F = 265.533)
C21 : 0	nd	0.12	nd	0.14	NS (F = 0.500)
C22 : 0	0.55	0.78	0.69	nd	S (F = 33.580)
C23 : 0	0.20	nd	0.41	0.63	S (F = 462.330)
C24 : 0	nd	0.27	nd	0.12	S (F = 112.500)
C14 : 1	0.29	0.43	0.38	0.13	S (F = 173.580)
C16 : 1	5.17	4.32	5.32	6.46	S (F = 1935.063)
C18 : 1	18.29	17.84	18.05	14.43	S (F = 1331.210)
C20 : 1	2.32	4.02	4.14	3.29	S (F = 1121.747)
C22 : 1	2.13	3.80	2.60	2.37	S (F = 449.332)
C18 : 2	11.64	12.87	11.62	8.89	S (F = 1131.053)
C18 : 3	nd	0.21	nd	0.01	S (F = 800.000)
C20 : 4	2.48	2.66	2.74	1.54	S (F = 491.253)
C20 : 5	2.05	2.86	2.80	1.86	S (F = 290.916)
C22 : 5	1.40	1.64	1.70	1.00	S (F = 161.440)
C22 : 6	1.50	2.30	1.60	0.48	S (F = 12549.000)
ε SAFA	52.73	47.05	49.05	59.54	S (F = 120.740)
ε MUFA	28.20	30.41	30.49	26.68	S (F = 13.625)
ε PUFA	19.07	22.54	20.46	13.78	S (F = 55.881)

*** Not detected**
SAFA= Saturated fatty acids; MUFA= Mono unsaturated fatty acids;
PUFA= Poly unsaturated fatty acids
Fatty acid content is expressed as area percent FAMEs and % (by dry weight).
Each value is a mean of three replicate samples.
S = Statistically significant (P< 0.05); NS = Statistically non significant (P > 0.05)
Values in parenthesis are the Statistical One way- ANOVA - F-value.

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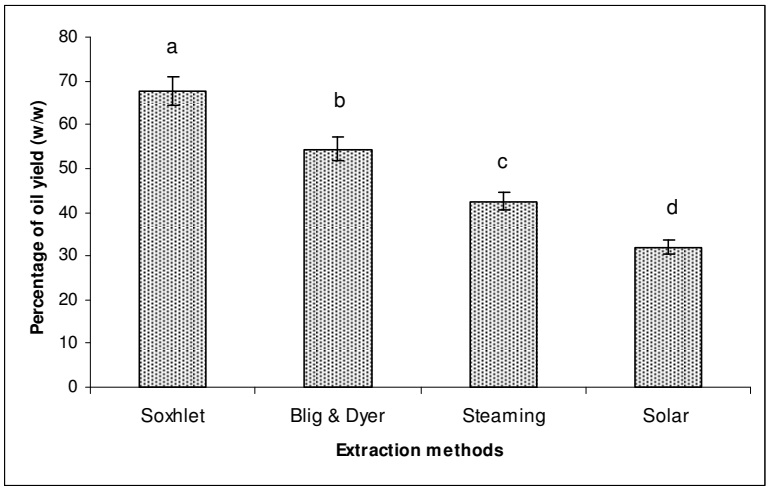


Figure: 2 Percentage oil yield (w/w) from different methods of extraction of *O. niger* liver Each value is a mean of three replicate samples; Figure with different alphabets is statistically significant (P < 0.05)

Discussion

According to Le Cren (1951) length of the fish is often more rapidly and accurately measured than weight, for calculating weight from length, it may also give indication of taxonomic difference and events in the life history of the studied fish. The general expectation is that the weight of fishes would vary on the cube of length (Lagler, 1952; Beverton & Holt, 1957; Brown, 1957; Rounsefell & Everhart, 1959; Brody, 1965). This aspect has been taken into consideration in the present study of length-weight relationship of trasfish *O. niger* of Southwest coast of India and the correlation coefficient obtained for the relation between them was statistically significant.

Shenoy & Dey (1984) reported that the liver of shark usually weighs about one fourth (25%) of the total weight of the fish. In Balistid fish *Sufflamen capistratus,* the percentage was 5.6% (George *et al*., 1976). Whereas in *O. niger,* the percentage of liver to the body weight was 9.15% in the smallest weight group (45-47g) and 6.21 % in the largest weight group (118-120g). The result obtained in the present study elucidates the impact of method of extraction on oil yield as well as its properties. The oil extracted from the liver of *O. niger* was higher in Soxhlet extraction and Bligh and Dyer methods. The reason for the lowest yield of oil in the steaming and the solar extraction methods may be due to rupture of the liver cells during processing (Sunarya *et al*., 1992; Immanuel *et al*., 2009). Bailey (1942) found after decanting the first portion of free oil from the steamed and centrifuged dogfish liver, the residue gave oil yield of 2 to 10 % when it was solvent extracted. The Soxhlet and Bligh and Dyer extractions gave results in agreement with the data for the oil content of dogfish liver caught from many areas of Pacific region and Japan, which have been cited as 50-70% (Brody, 1965; Kayama *et*

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al., 1969; Kizevetter, 1973; Murrey & Burt, 1983).

Fats have definite melting point. They are usually low and vary in each case. The melting point of a fat is always higher than the temperature at which it solidifies. The melting points of natural fats are not sharp because they are mixture of several fats. Presence of saturated fatty acids in fact increases the melting point and vice versa. This property causes the fat to be liquid or oil state at room temperature. Solidification temperature of beef fat is 36^{O}C (Shanmugam, 1990). Similarly in the present study the solidification point for the oils remained at 29±0.5^{O}C in all four methods.

Shanmugam (1990) pointed out the specific gravity of solid fat (0.86) to be less than the specific gravity of liquid fat (0.91 to 0.95). The specific gravity of *O. niger* liver oil extracted by the four methods have the same value of 0.95 (at 29^{O}C) which describes that the oil extracted from the fish is liquid fat (0.91 to 0.95).

Fats have definite angles of refraction and any deviation from the normal value indicate mixture of fats. According to Pillai (1963), the refractive index of *O. niger* liver oil extracted by steaming method has 1.45µ at 28^{O}C, whereas in the present study the refractive index was slightly varied in between 1.42 and 1.48µ at 29^{O}C in the four methods.

All fats and oils contain 0.1 to 2% complex alcohol known as sterols (Jacobs, 1965; Young, 1986) and this level was varied in the oil extracted by various methods. In the present study in Bligh and Dyer and steaming extraction methods, the level of cholesterol was almost 50 % higher than the other two methods. But Sunarya *et al*. (1992) found that the cholesterol content was in similar level (1.1%) in the three different methods of extraction of oils from dogfish liver (Bligh & Dyer, Soxhlet and steaming methods). In dogfish liver oil, Kayama *et al*. (1969) reported 0.93% cholesterol. Iwasaki and Harada (1984) reported 1.11% cholesterol in blue shark liver oil.

The oils of fish and other marine animals are characterized by a large group of saturated and unsaturated fatty acids, which are commonly associated with mixed triglycerides. In addition to these, the oils contain small quantity of fatty acids in phospholipids. Compared to body fat, liver oils and oils from particular organs of fish and other marine animals can often contain large amount of fatty acids associated with phospholipids, glycerol, ethers and wax esters (Lovern, 1962; Young, 1986; Davidson & Cliff, 2002; Garcia *et al*., 2004; Immanuel *et al*., 2009).

In the present study, the total saturated fatty acid content of the fish *O. niger* liver oil extracted by different methods were much varied (47.05-59.54%). The saturated fatty acids of marine animals are ranged between 17.3 and 61.6%. For instance, in cod liver oil, the saturated fatty acid percentage was 17.3 and in Atlantic herring oil and Menhaden oil, it was 21.5 and 33.3% respectively (New, 1987). In Madura anchovy and gizzard shade, it was 48.9 and 61.6% (Nair & Gopakumar, 1977) etc. Nair

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& Gopakumar (1982) studied the saturated fatty acid percentage of *Tilapia mossambica* both brackish water and fresh water separately and they found that *T. mossambica* brackish water species has 50.67 to 53.45% of saturated fatty acids, whereas fresh water species has 47.80 to 48.56% of saturated fatty acids. Ackman *et al.* (1963) pointed out the oil from Newfoundland capelin (*Mallotus villosus*) associated with 22.60 to 23.50% of saturated fatty acids and also Indian oil sardine has 40.32 % of saturated fatty acids (Raj, 1993). Similar to the above, in the present study also a remarkable variation was found on saturated fatty acid level, it is because of the differences between oil extraction methods. For instance, the saturated fatty acid level of oil samples extracted by Soxlet, Blig & Dyer, Steaming and Solar extraction methods was 52.73, 47.05, 49.05 and 59.54% respectively. In accordance with this, Immanuel *et al* (2009) reported that the saturated fatty acid level of liver oil samples of *S. capistratus* was ranged between 36.32 and 63.84% in the above extraction methods.

The monounsaturated fatty acid content of oils of marine fishes varied from 16.9 to 77.1%. Madura anchovy fish oil has the maximum level of 16.9% monounsaturated fatty acids (Nair & Gopakumar, 1977). New (1987) reported the highest level of 77.1% monounsaturated fatty acids in cod liver oil. The oil separated from Atlantic herring contains 73.9% of monounsaturated fatty acids, which was separated from the whole body (New, 1987). Meanwhile very low percentage of monounsaturated fatty acids was separated from the whole body oil of Madura anchovy. Liver oil of fish normally contains high level of mono-unsaturated fatty acids (New, 1987; Davidson & Cliff, 2002), but in the present study, the monounsaturated fatty acid content of different oil samples extracted by various methods was ranged from 26.68 to 30.49%. Similarly, Immanuel *et al.* (2009) reported the monounsaturated fatty acid level of *S. capistratus* liver oil samples extracted by different methods was ranged from 23.76 to 40.90%.

In *O. niger* liver oil, oleic acid (C18: 1) and palmitoleic acid (C16: 1) were found to be the major monoenic acids of the oil extracted by various methods. These two acids were found to be more or less same percentage reported for sardine oil by Gopakumar & Nair (1966) and less in dog fish liver oil reported by Sunarya *et al.* (1992). C14: 1 was absent in several fish oils (e.g. dog fish liver oil: Sunarya *et al.,* 1992). But in *O. niger* liver oil, the amount of C14: 1 is too low (0.13 to 0.43%), whereas C20: 1 and C22: 1 were in higher percentage in dogfish liver oil than the liver oil of *O. niger*. In the present study, the polyenic acids (PUFA) constitute 13.78 to 22.54% of the total fatty acids. Among these cislinoleic acid (C18: 2) was the major constituent (8.89 to 12.87%). In evidence to this, Immanuel *et al* (2009) also reported that cislinoleic acid was the dominant fatty acid among the PUFA and the level of this particular acid recorded was ranged between 5.05 and 11.85%. But in certain fish oils the cislinoleic acid

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reported was very low or absent. For eg., in New found land capelin fish oil, it was absent (Ackman *et al*., 1963), whereas it is less in Atlantic Herring oil (1.7%), Menhaden oil (2.0%), Cod liver oil (1.8%) and Pollack liver oil (5.0%) (New, 1987; Akiyama & Dominy, 1989).

According to Ackman (1982) in marine oils, the dominant PUFA are those of the series of C20: 5n-3 and C22: 5n-3, but in the present study the percentage of these two acids occupied second position next to C18: 2 in the PUFA series. C18: 3 were present in trace in solar and Bligh and Dyer methods, but in the other two methods it was not detected. In Atlantic herring and cod liver oils also this acid was very low (New, 1987). Among C20 PUFA series, C20: 4 and C20: 5 were the major acids, i.e., 1.54 to 2.74% and 1.86 to 2.86% respectively in the present study. Whereas in cod liver oil C20: 4n-6 is in trace amount, but presence of 20: 5n-3 was relatively higher amount (8.9%) (New, 1987). In dogfish liver oil, C20: 4n-3 was absent and C20: 5n-3 was representing 4.4 to 4.8% (Sunarya *et al*., 1992). In pollack liver oil, C20: 4n-3 was absent, but C20: 5n-3 was present in fairly good amount of 12% (Ackman *et al*., 1963).

In the C22 PUFA series, only C22: 2, C22: 3 and C22: 4 were not detected in the present study. In dogfish liver oil also these series of PUFA were absent except C22: 5 and C22: 6 (Sunarya *et al*., 1992). The percentage of C22: 5n-3 and C22: 6n-3 in dogfish liver oils was 2.3 to 2.6% and 9.9 to 11.7%, respectively. But in the present study the amounts were 1.0 to 1.7% (C22: 5n-3) and 0.48 to 2.30% (C22: 6n-3) respectively. In Atlantic herring oil 1.0 and 3.8%, Menhaden oil 1.7 and 7.9%, cod liver oil 1.6 and 9.3% of C22:5 and C22: 6 (New, 1987).

Considering the quantity of oil yielded and their biochemical constituents, Soxhlet and Bligh and Dyer methods were found to be suitable for *O. niger* liver oil extraction.

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مقايسه ساختار اسيدهاي چرب روغن كبد ماهي *Odonus niger* در سواحل جنوب غربي هند

ج. امانوئل* و ا. پالا وسام

تاريخ دريافت: مرداد ۱۳۸۷ تاريخ پذيرش: خرداد ۱۳۸۸

چكيده

به منظور يافتن جايگزينی برای روغن با درجۀ بالائی از اسيدهای چرب غيراشباع و با قيمت پايين‌تر، ماهی كم ارزشی به نام *Odonus niger* مورد تجزيه و بررسی قرار گرفت. در اين تحقيق وزن بدن و وزن كبد ماهی مطالعه شد. نتايج نشان داد كه به ازاء افزايش يک گرم وزن بدن ماهی، وزن كبد تا ۰/۰۴ گرم می‌تواند افزايش يابد. ظرفيت بازدهی روغن كبد ماهی با چهار روش مختلف به نامهای Soxhlet، Bligh & Dyer، Direct steaming و Solar extraction اندازه‌گيری شد. درصد محصول روغن در روش استخراج با Soxhlet بالا بود (۶۷/۷ درصد)، اما در روش Bligh & Dyer ۵۴/۳ درصد و در روش Direct steaming ۴۲/۵ درصد بود. كمترين مقدار روغن در روش Solar extraction به ميزان ۳۲ درصد بدست آمد. نقطه انجماد برای تمام روغنها برابر با ۰/۵±۲۹ درجه سانتيگراد بود. وزن مخصوص ۰/۹۵ تا ۰/۹۶ و ضريب شكست نور ۱/۴۲ تا ۱/۴۸ ميكرون بود و اختلاف معنی‌داری برای چهار روش استخراج روغن وجود نداشت. مقدار كلسترول در روغنهايی كه به دو روش Bligh & Dyer و Direct steaming استخراج شده بودند بيشترين مقدار (۱۹۹۱ و ۲۰۵۹ ميلی‌گرم در ۱۰۰ ميلی‌ليتر) ولی ۵۰ درصد كمتر از روشهای ديگر بود. درصد PUFA در كل اسيدهای چرب روغنها بترتيب ۱۳/۷۸، ۲۰/۴۶، ۱۹/۰۷ و ۲۲/۵۴ (از نظر وزنی) در روشهای Solar extraction، Direct steaming، Soxhlet و Bligh & Dyer بود. بنابراين خصوصيات فيزيكی و شيميايی روغن كبد ماهی *Odonus niger* تحت تاثير روشهای مختلف استخراج روغن قرار دارد. همچنين از اين مطالعه مشخص گرديد كه روش Bligh & Dyer برای استخراج روغن كبد ماهيان دريايی بدون از دست دادن مواد مغذی آن، روش مناسبی است.

كلمات كليدي: *Odonus niger*، PUFA، FFA، سوكسله، بلای ودايز، بخار مستقيم، استخراج خورشيدی

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