

Properties of Fats and Oils contained in Various Parts of a Sperm Whale Body

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Introduction

Numerous studies have been made since the olden times on whale oil.¹⁻³³⁾ Many works have been made on its physico-chemical properties, on the components of its fatty acids and its saponifiable matter and their properties. However, these studies have chiefly been confined to the oils from whale blubber, bones and head cavity and there has been very little evidence of chemical studies made on oils from large and small intestines, liver, kidney and other organs. It seemed that it would not only be interesting to make a study of oils from various organs from the point of fat metabolism but also necessary from the point of their utilization. Therefore, studies in this line were made.

Experimental materials

The present experiments were carried out with 2 heads of sperm whales (*Physeter macrocephalus* L.) which were caught off Kinkazan point (Miyagi Prefecture in the northeastern part of Japan). One was a male (Sperm Whale B), measuring 34 feet long, caught in September 1946, and the other, also a male (Sperm Whale A), measuring 35 feet long, caught on 23rd. September 1947. Each individual animal was dissected in the dissecting room, various parts collected and those from which oil can be obtained by boiling, i. e. skins, large and small intestines, were boiled on the spot. Those difficult to put to this procedure, i. e. liver and large and small intestines of the Sperm Whale A, were frozen and sent to the laboratory.

In the laboratory, these organs were defrosted, dehydrated by treatment with alcohol, carbon dioxide then blown in and dried in vacuum. After this dried organs were pulverized, it was extracted by ether in a Soxhlet extractor. The alcohol used for dehydration was evaporated under reduced pressure and dried and this residue was shaken with ether. This ether and that from the Soxhlet extractor were brought together and after drying with anhydrous sodium sulfate, the ether solution was dropped into

dry acetone while stirring constantly and the phospholipid precipitated was filtered off.^{3,4)}

Acetone and ether were driven off under reduced pressure in carbon dioxide stream and some oil was obtained. The ether extract from the liver of Sperm Whale B amounted to 11.73% of dried matter. The oil from the head cavity was collected when the oil flowed out at the time of dissection. This head oil (oil from the head cavity) is a white solid at a room temperature, forms a pale, yellow liquid at (around) 30° and precipitates about half the amount of white, cloudy crystals at around 25°.

The blubber oil (Oil from the skin) is pale yellow. The oil obtained from large and small intestines is yellow, but that obtained by ether extraction is brown. During the summer, intestinal oil is liquid but precipitates solid matter during the winter (11°C). Liver oil is brown and remains liquid, although slightly viscous, all through the winter.

These samples were treated with acid clay or activated charcoal and yellow oils were obtained which were used for the following experiments.

Experiment

Neutral oils— With the above samples, specific gravity, coefficient of refraction, acid value and saponification value were measured in an ordinary manner, and the iodine value by Wijs' method. Saponification was limited to 2 hours. Vitamin A content was also measured by Beckmann's spectrophotometer. The results obtained are shown in Tables I and II.

Table I. Neutral Oils from Sperm Whale A.

Parts	Appearance	$d_{4}^{25^{\circ}}$	$n_{D}^{40^{\circ}}$	Acid Value	Sapon. Value	Iodine Value	Non-sapon. matter	Vitamin A (I. U.)
Head oil	White solid	0.8744	1.4500	0.73	140.71	55.01	44.98	103
Blubber	Pale yellow liquid	0.8779	1.4570	0.75	131.08	82.33	35.51	370
Small intestine	Pale yellow liquid	0.8879	1.4570	2.01	156.84	78.88	17.35	865
Large intestine	Pale yellow liquid	—	1.4522	13.36	154.48	77.71	19.18	—
Liver	Brown, viscous liquid	—	1.4711	2.64	165.34	92.41	19.01	12,655

Table II. Neutral Oils from Sperm Whale B.

Parts	Appearance	$d_{4}^{20^{\circ}}$	$n_{D}^{32^{\circ}}$	Acid Value	Sapon. Value	Iodine Value
Head oil	White solid	0.8752	1.4689	0.52	142.35	57.57
Blubber	Pale yellow liquid	0.8792	1.4696	0.36	127.89	82.13
Small intestine	Pale yellow liquid	0.9056	1.4721	1.03	—	78.23
Large intestine	Pale yellow liquid	0.9054	1.4724	1.01	—	79.41
Liver	Dark brown semi-solid	—	1.4861	18.83	155.91	82.12

Although the whales A and B are different individuals, all values in the two above tables are similar, showing that there are very little difference between the individual animal.

Non-saponifiable matter— The samples were saponified with alcoholic potash, water added and shaken 4 times with ether. combined ether solution was washed with water, dried with sodium sulfate and ether evaporated under blowing in carbon dioxide.

Non-saponifiable matter from all the samples were a pale yellow solid during the winter (11°C) and the properties are as shown in Table III. The melting points were determined in a capillary tube, values being that of the beginning and end of melting.

Table III. Properties of Non-Saponifiable Matter from the Sperm Whale A.

Parts	Appearance	n_D^{40}	Melting point (°C)	Iodine value (Wijs')
Head oil	Pale yellow solid	1.4450	35.0—37.0	39.08
Blubber	Pale yellow solid	1.4500	20.5—24.0	71.74
Small intestine	Pale yellow solid	1.4490	29.5—31.8	51.72
Large intestine	Pale yellow solid	1.4500	29.0—31.8	50.53

Fatty acids— The aqueous solution obtained by the removal of nonsaponifiable matter was evaporated under reduced pressure to remove alcohol, hydrochloric acid added and the freed fatty acid extracted by ether. This was treated in the same way as for non-saponifiable matter. Of the fatty acids obtained:

Mixed fatty acids from the skin oil was a pale brown liquid during the winter (11°C) precipitating some solid fats; That from head oil was pale yellow solid, with a mixture of some crystalline solid fats; and those from large and small intestines were a yellow solid. Properties of these fatty acids are shown in Table IV.

Table IV. Mixed Fatty Acids from the Sperm Whale A.

Parts	n_D^{40}	Melting point (°C)	Iodine value (Wijs')	Neutralization Value
Head oil	1.4437	16.0—20.0	56.44	246.68
Blubber oil	1.4511	13.5—18.0	80.57	199.22
Small intestine oil	1.4530	28.0—31.0	79.54	194.66
Large intestine oil	1.4518	28.0—31.5	81.85	195.27

Solid and Liquid Acids— Solid and liquid fats were obtained from the mixture of fatty acids using about 10 g of each sample according to Twitchell's method⁽³⁵⁾. The solid acids here obtained were white solids, and liquid acids from intestinal and head oils were yellow, that from blubber

oil, yellowish brown. The properties of these solid and liquid acids are shown in Tables V and VI.

Table V. Solid Fatty Acids from the Sperm Whale A.

Parts	Appearance	Percentage against total fatty acid	n_D^{60}	Melting point (°C)	Iodine value (Wijs')	Neutralization value
Head oil	White solid	21.31%	1.4289	38—39	3.06	250.63
Blubber	White solid	10.07%	1.4352	50—52	14.56	213.62
Small intestine	White solid	18.64%	1.4363	50—52.5	15.39	211.36
Large intestine	White solid	19.29%	1.4368	50—52.5	11.48	210.49

Table VI. Liquid fatty acids from the Sperm Whale A.

Parts	Appearance	Percentage against total fatty acid	n_D^{40}	Iodine value (Wijs')	Neutralization value
Head oil	Yellow liquid	78.69%	1.4450	73.93	236.12
Blubber	Yellowish brown liquid	89.93%	1.4522	92.26	194.72
Small intestine	Yellow liquid	81.36%	1.4550	95.07	187.25
Large intestine	Yellow liquid	80.71%	1.4542	91.03	187.83

Summary and Discussions

1) The blubber oil of the sperm whale, especially the oil from its head cavity, is composed of fatty acids of small molecular weight and is unique to it except the butter fat. As a result of the present experiments, it has been found that the average molecular weight of fatty acids was the smallest in those contained in head oil, that from the blubber oil next and followed by large and small intestine and liver oil, which contained the large molecular weight acids although the values were approximately similar (estimated from the amount of non-asponifiable matter of neutral fats and the saponification value).

Both the solid and liquid acids from the head oil were of small molecular weight compared to other oils from other organs.

2) The degree of unsaturation of mixed fatty acid is the smallest in the head oil, those from blubber, large and small intestines are about the same and are larger. This seems to be due to the fact that the head oil contains a large amount of solid acids and that the degree of unsaturation of its liquid acid is small compared to the oils of other organs.

3) It is known that sperm whales feast largely on quantities of squids proof of which was borne out by the discovery of a large amount of them in the stomachs of the sperm whales used for these experiments. In order

to find the relationship between the specific nature of sperm whales and the oil of squids devoured as their chief food, reference was made to the analysis of the oil from a certain kind of squids caught in the Hokkaido, Japan, by Mitsumaru Tsujimoto³⁶⁾. This analysis showed that this oil contained a very small amount of non-saponifiable matter and its degree of unsaturation was exceedingly high. Comparison of similar data by E. André and H. Canal³⁷⁾ showed that the degree of unsaturation was also high in the French squid oil but contained more non-saponifiable matter than the Japanese squid oil, values being near those of sperm oil. According to these French investigators, the non-saponifiable matter contains, differing from the sperm oil, no aliphatic alcohols, either saturated or unsaturated. From these facts, it is assumed that sperm whales utilize these squid oils to turn into its own oil.

4) As has been shown in the foregoing, sperm whales possess a large amount of wax so that it gives abnormally high amount of non-saponifiable matter. In the present experiments, the amount of non-saponifiable matter in the head and blubber oil was exceedingly large but that from large and small intestine and liver oil was only one-half of the former, being about the medium between the oil of sulfur bottom and that of sperm whale. It is interesting to note that the average molecular weight of fatty acids and the amount of non-saponifiable matter are in an inverse ratio in the above two.

It would be interesting to study the relationship between these facts and the fat metabolism in whale bodies and if such a relation does exist, what significance it has. These must be left for the future.

5) The degree of unsaturation of the non-saponifiable matter is the smallest in head oil, followed by the oils of large and small intestines which were about the same, and largest in the blubber oil.

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References

- 1) Mitsumaru Tsujimoto: *J. Ind. Chem., Japan.* **13**, 1267—1246 (1910).
- 2) Mitsumaru Tsujimoto: *J. Tokyo Ind. Lab.*, **15** (10), 1—80 (1920).
- 3) Mitsumaru Tsujimoto: *J. Ind. Chem., Japan.* **20**, 41—44 (1921).

- 4) Mitsumaru Tsujimoto: Chem. Umschau. **30**, 33—36 (1923); J. Ind. Chem., Japan. **26**, 608—620; Tokyo Ind. Lab., **18** (2), 103—123 (1923).
- 5) Mitsumaru Tsujimoto: Chem. Umschau. **32**, 127—8 (1925).
- 6) Mitsumaru Tsujimoto: Chem. Umschau. Fette. Oele. Wache und Harze, **32**, 202—4 (1925).
- 7) Mitsumaru Tsujimoto and Hosuke Kimura: Tokyo Ind. Lab., **22** (12), 53—63 (1927).
- 8) Mitsumaru Tsujimoto: Tokyo Ind. Lab., **23** (3), 61—63 (1928).
- 9) Mitsumaru Tsujimoto and Hanji Koyanagi: J. Ind. Chem., Japan. **40**, 391—395 (1937).
- 10) Mitsumaru Tsujimoto and Hanji Koyanagi: J. Ind. Chem., Japan. **40**, 694—696 (1937).
- 11) Emile Andre and Th. Francois: Compt. rend. **183**, 663—675 (1926).
- 12) Emile Andre and Th. Francois: Compt. rend. **185**, 279—281 (1928).
- 13) Emile Andre and Th. Francois: Bull. Soc. Chim. biol. **9**, 117—125 ().
- 14) Emile Andre and Th. Francois: Compt. rend. **182**, 497—499 (1925).
- 15) Shushi Toyama: Tokyo Ind. Lab., **22** (11), 225—227 (1927).
- 16) Shushi Toyama: J. Ind. Chem., Japan. **30**, 519—527 (); Tokyo Ind. Lab., **22** (11), 189—224 (1927).
- 17) Shushi Toyama: J. Ind. Chem. **30**, 527—532 (1927).
- 18) Shushi Toyama and Chitaro Tsuchiya: J. Japan Chem. Soc. **56**, 1072—1077 (1935).
- 19) Shushi Toyama and Chitaro Tsuchiya: 1st Report. J. Japan Chem. Soc., **56**, 1050—1054 (1935); 2nd Report. *ibid.*, **56**, 1055—1059 (1935).
- 20) Shushi Toyama and Chitaro Tsuchiya: J. Ind. Chem., Japan. **38**, 627—631 (1935).
- 21) Shushi Toyama and Goroku Toyama: J. Japan Chem. Soc., **56**, 1316—1319 (1935).
- 22) Shushi Toyama and Goroku Toyama: J. Japan Chem. Soc., **56**, 1077—1080 (1935).
- 23) Shushi Toyama and Chitaro Tsuchiya: J. Japan Chem. Soc., **56**, 1313—1315 (1935).
- 24) Shushi Toyama: J. Japan Chem. Soc., **59**, 810—814 (1938).
- 25) Seiichi Uyeno: J. Ind. Chem., Japan. **38**, 1340—1344 (1935).
- 26) Seiichi Uyeno and Ryosei Koyama: Bull. Chem. Soc. Japan, **11**, 394—403 (1936).
- 27) Seiichi Uyeno and Ryosei Koyama: J. Japan Chem. Soc., **57**, 1—9 (1936).
- 28) Seiichi Uyeno: J. Ind. Chem. Japan., **41**, 643 (1938).
- 29) Koichiro Ura: J. Ind. Chem. Japan, **11**, 854—864 (1908).
- 30) Shigetada Tanimura: J. Marine Prod. Inst., **15** (2), 37—54 (1920).
- 31) T. P. Hilditch and J. A. Lovern: J. Soc. Chem. Ind. **47**, 105—111 (1928); *ibid.*, **48**, 359—365; *ibid.*, **48**, 365—368 (1929).
- 32) S. Schmidt-Nielson and A. Flood: Kgl. Norske Videns Kab. Scks Kab. Foresh. **5**, 198—201 (1932).
- 33) Tei Ando, Sokenori Uzawa and Isao Shigetomi: J. Japan Mar. Prod. Assoc., **10**, 1, 17 (1941).
- 34) W. R. Bloor and Ruth H. Snider: J. Biol. Chem. **87**, 399.
- 35) E. Twitchell: J. Ind. Eng. Chem. **13**, 9, 806—807 ().
- 36) Mitsumaru Tsujimoto and Hosuke Kimura: J. Ind. Chem., Japan. **30**, 865 (1927); Cf. Tsujimoto: J. Ind. Chem., Japan. **17**, 201, 1300 (1914).
- 37) E. Andre and H. Canal: Compt. rend. **183**, 152 (1926).