STUDIES ON THE OIL OF BLACK RIGHT WHALE IN THE NORTHERN PACIFIC OCEAN

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INTRODUCTION

A number of studies have been made in whale oil from olden time. However, the oil of black right whale, *Eubalaena glacialis*, has almost remained unexplored to this day. Because, our ancestors had caught a number of black right whales, so that we have all the world over been stopped to catch them for keeping of their resource.

The works studied on whale oils were chiefly concerned with its physical-chemical properties. But only a little work was made in the study of the oils contained in various parts of a whale body and component fatty acids. These works seems to be important from the view points of fat metabolism in whale bodies and the utilization of whale oils.

Regarding the differences in the characteristics of the oils contained in various parts of a whale body, Drs. M. Saiki and T. Mori[1)-3)], and Messrs. H. Watanabe and K. Suzuki[4),5)] studied several kinds of whales. Reviewing the works done on the black right whale oil, we have merely been reported by Dr. M. Saiki.[6)] He studied the chemical characteristics of the oils contained in some blubbers of black right whale, which had been caught 102 miles 80° off " Kinkazan " (Miyagi prefecture in the north-eastern part of Japan) on 23rd May, 1956. However, this work was very simple, so that we can say that we have no sufficient work on the differences in the characteristics of the oils contained in various parts of a black right whale body. Further, as to the study on the component fatty acids of the black right whale oil, we have not been reported yet.

The writers were fortunate enough to obtain the oils in various blubbers, meats and viscera of three black right whales and examine their properties including component fatty acids.

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EXPERIMENTS AND RESULTS

I

The present experiment was carried out with three black right whales[7)], which were

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caught in southern sea of Kodiak Island (N 55°53′~54′, W 153°4′~6′) on the 22nd August, 1961 by the " Kyokuyōmaru " Fleet (Fig. 1). Sex, presumptive age and body length of three whales are shown in Table 1.

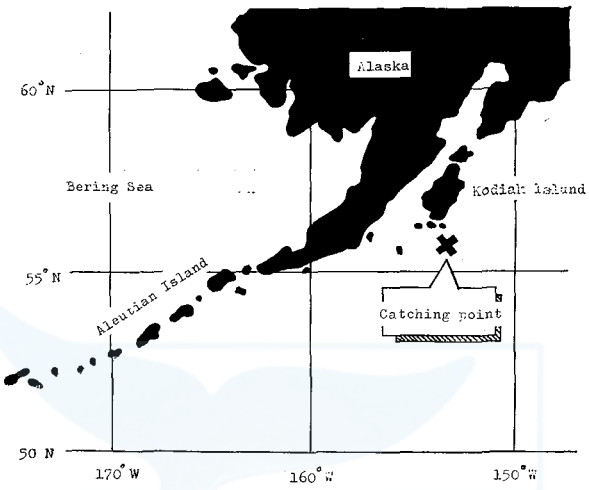

Fig. 1. Catching place of black right whale in the Northern Pacific Ocean

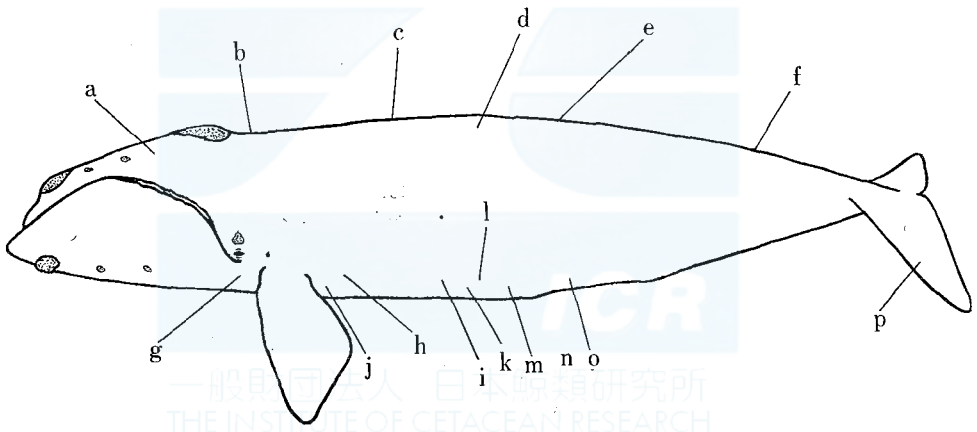

Fig. 2. Various blubbers and meats of black right whale

a) Brain blubber. b) Blow-hole blubber. c) Blubber of hind part of blow-hole. d) Back meat. e) Middle back blubber. f) Posterior back blubber. g) Blubber of " Dendō " in Japanese. h) Thoracic meat (" Munaita " in Japanese). i) Anterior abdominal blubber. j) Thoracic blubber. k) Umbilicus blubber. l) Abdominal blubber. m) Blubber of fore part of genital aperture. n) Genital aperture blubber. o) Anus blubber. p) Tail fluckes blubber.

These whales were treated on the boat immediately after catching as follows: At first, they were dissected and divided into various meats, blubbers (Fig. 2) and organs. Each portion was immediately refrigerated at −20°C. Returning to port,

these materials described above were sent to the laboratory. In the laboratory, the oils contained in various blubbers were obtained by boiling these blubbers in water. On the other hand, the oils in various meats and organs were extracted with acetone in an atmosphere of nitrogen gas.

The specific gravity, refractive index, acid value, saponification value and unsaponifiable material content (%) of the obtained oils were measured in the usual manner and the iodine value was determined by the Wijs method. The results obtained are shown in Tables 2~10.

TABLE 1. DETAILS OF BLACK RIGHT WHALES, *EUBALAENA GLACIALIS*

Whale No.	Sex	Presumptive age	Body length (m.)
A	Male	More than 12	17.1
B	Male	More than 12	17.0
C	Male	More than 9	15.1

TABLE 2. PROPERTIES OF THE OILS CONTAINED IN VARIOUS BLUBBERS AND MEATS OF BLACK RIGHT WHALE A

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content(%)
Brain blubber	56.31	1.4765	0.9183	0.3	188.3	134.7	0.64
,,	54.48	1.4715	0.9175	0.6	189.5	131.2	0.81
Blubber of hind part of blow-hole	55.57	1.4755	0.9216	0.1	194.1	125.9	0.84
,,	57.95	1.4745	0.9230	0.2	193.6	123.7	0.79
Middle back meat	66.73	1.4745	0.9246	0.7	188.2	137.3	0.98
,,	70.80	1.4735	0.9231	1.0	187.9	143.7	0.91
,,	68.21	1.4760	0.9229	1.2	188.4	139.1	1.12
Posterior back meat	60.31	1.4706	0.9119	0.7	193.5	124.7	0.73
,,	63.42	1.4745	0.9190	0.5	194.3	122.4	0.77
,,	66.59	1.4735	0.9182	0.5	193.5	126.6	0.88
,,	64.87	1.4725	0.9189	0.3	191.9	129.9	0.91
Thoracic meat	42.98	1.4740	0.9233	0.7	192.7	121.4	0.62
,,	45.56	1.4723	0.9249	0.9	194.1	122.2	0.80
Anterior abdominal blubber	53.39	1.4751	0.9255	0.3	192.2	130.3	1.02
Abdominal blubber	54.99	1.4749	0.9243	0.7	191.9	126.3	0.89
,,	52.19	1.4768	0.9259	0.5	191.7	130.6	1.27
Blubber of " Dendō "	38.61	1.4739	0.9218	0.4	191.4	126.1	0.94
,,	35.62	1.4745	0.9239	0.5	190.9	128.3	0.97
Blubber of fore part of genital aperture	73.80	1.4745	0.9187	0.9	188.6	142.6	1.09
,,	73.01	1.4740	0.9195	1.1	187.9	139.9	0.89
Tail flucks blubber	40.49	1.4755	0.9203	0.9	190.5	123.6	0.81
,,	38.47	1.4704	0.9229	0.7	194.3	119.7	0.69
,,	37.75	1.4713	0.9215	0.9	192.7	124.1	0.98
Back meat	0.68	1.4738	0.9259	1.9	190.8	128.0	1.15

TABLE 3. PROPERTIES OF THE OILS CONTAINED IN VARIOUS ORGANS OF BLACK RIGHT WHALE A

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Tongue	30.71	1.4757	0.9241	0.2	195.1	116.2	1.08
Oesophagus	14.56	1.4735	0.9218	0.4	192.0	129.1	0.59
,,	13.97	1.4746	0.9233	0.7	193.4	124.3	1.17
,,	11.83	1.4720	0.9209	0.6	194.1	126.7	1.06
Lung	28.19	1.4745	0.9211	0.7	190.6	133.2	1.28
,,	25.23	1.4715	0.9232	0.5	188.3	137.1	1.09
Stomach	7.89	1.4725	0.9189	0.6	193.2	123.2	1.03
,,	8.46	1.4725	0.9197	0.7	193.6	125.6	1.21
Small intestine	8.03	1.4720	0.9208	0.8	187.9	138.1	1.32
,,	7.61	1.4729	0.9221	0.9	189.2	135.9	1.18
Large intestine	3.06	1.4725	0.9233	0.8	190.4	127.8	1.10
Liver	10.41	1.4740	0.9219	1.5	190.5	129.4	1.72
Pancreas	9.37	1.4718	0.9203	0.5	190.9	128.7	1.31
,,	8.76	1.4700	0.9218	0.6	192.5	127.2	1.09
,,	7.91	1.4745	0.9226	0.8	194.1	123.7	1.22
Heart	2.48	1.4733	0.9191	1.1	193.6	124.1	1.48
Kidney	5.14	1.4740	0.9236	1.0	192.8	126.9	1.16
,,	7.28	1.4725	0.9220	1.3	190.9	129.7	1.28
,,	10.06	1.4700	0.9241	1.3	193.1	128.5	1.02
Testicle	8.13	1.4745	0.9251	2.2	196.0	116.7	1.33

TABLE 4. PROPERTIES OF THE OILS OF BLACK RIGHT WALE A

Kind of oils	Oil contents (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Blubber oils (23 samples)	35.62 ~ 73.80	1.4704 ~ 1.4768	0.9175 ~ 0.9259	0.1 ~ 1.2	187.9 ~ 194.3	119.7 ~ 143.7	0.62 ~ 1.27
Meat oil (1 sample)	0.68	1.4738	0.9259	1.9	190.8	128.0	1.15
Organ oils (20 samples)	2.48 ~ 30.71	1.4700 ~ 1.4757	0.9189 ~ 0.9251	0.2 ~ 2.2	187.9 ~ 196.0	116.2 ~ 138.1	0.95 ~ 1.72

TABLE 5. PROPERTIES OF THE OILS CONTAINED IN VARIOUS BLUBBERS AND MEATS OF BLACK RIGHT WHALE B

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Blubber of hind part of blow-hole	56.71	1.4735	0.9233	0.6	190.7	131.4	0.81
,,	57.44	1.4735	0.9221	0.6	193.9	124.0	0.68
Middle back meat	66.36	1.4740	0.9197	1.0	187.3	137.9	0.77
Posterior back meat	64.39	1.4699	0.9208	0.4	191.9	123.5	0.55
Thoracic blubber	47.03	1.4745	0.9190	0.7	193.1	127.2	0.73
Anterior abdominal blubber	61.78	1.4715	0.9209	0.8	190.3	135.0	0.73
,,	58.53	1.4762	0.9227	0.6	190.7	137.4	0.88
,,	56.91	1.4745	0.9215	1.2	188.1	141.2	0.76
Abdominal blubber	53.43	1.4755	0.9188	1.0	189.5	137.2	0.82
,,	56.22	1.4760	0.9201	1.4	187.8	142.1	0.95
Blubber of " Dendō "	36.11	1.4718	0.9239	0.4	189.8	134.5	0.78
Blubber of fore part of genital aperture	70.85	1.4753	0.9241	0.5	190.9	137.1	0.84
,,	68.57	1.4725	0.9229	0.5	190.6	133.5	0.69
Tail flucks blubber	40.89	1.4697	0.9208	0.5	195.1	116.9	0.76
,,	42.52	1.4743	0.9220	0.3	194.0	122.7	0.85
,,	38.35	1.4701	0.9231	0.9	195.4	117.8	0.70
Back meat	0.93	1.4735	0.9190	1.2	193.5	126.3	0.99
Thoracic meat	0.83	1.4730	0.9222	0.9	190.9	130.5	1.16

TABLE 6. PROPERTIES OF THE OILS CONTAINED IN VARIOUS ORGANS OF BLACK RIGHT WHALE B

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Tongue	31.85	1.4747	0.9208	1.0	194.0	113.3	1.06
Oesophagus	11.98	1.4769	0.9238	0.3	194.2	120.9	1.13
,,	14.32	1.4748	0.9218	0.5	192.9	125.8	0.97
Stomach	7.42	1.4750	0.9238	0.8	191.4	129.9	1.31
,,	6.55	1.4766	0.9245	0.9	191.1	125.6	1.24
Small intestine	8.02	1.4745	0.9229	0.6	187.3	143.2	1.40
Large intestine	5.88	1.4729	0.9201	0.4	193.5	126.2	1.52
,,	6.31	1.4761	0.9227	0.7	193.1	123.2	1.30
,,	6.95	1.4725	0.9191	0.3	192.7	122.3	1.44
Liver	10.49	1.4715	0.9233	1.7	191.8	127.6	1.66
Heart	2.82	1.4759	0.9227	0.7	192.2	127.1	1.79
Kidney	9.74	1.4750	0.9206	1.3	190.9	131.8	1.26
,,	10.97	1.4761	0.9221	1.1	190.6	130.3	1.47
Testicle	7.92	1.4733	0.9209	1.5	194.9	120.2	1.23
Epididymis	4.41	1.4740	0.9211	0.7	196.4	116.4	1.44

TABLE 7. PROPERTIES OF THE OILS OF BLACK RIGHT WHALE B

Kind of oils	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Blubber oils (16 samples)	36.11 ~ 70.85	1.4697 ~ 1.4762	0.9188 ~ 0.9241	0.3 ~ 1.4	187.3 ~ 195.4	116.9 ~ 142.1	0.55 ~ 0.95
Meat oils (2 samples)	0.83 ~ 0.93	1.4730 ~ 1.4735	0.9190 ~ 0.9222	0.9 ~ 1.2	190.9 ~ 193.5	126.3 ~ 130.5	0.99 ~ 1.16
Organ oils (15 samples)	2.82 ~ 31.85	1.4715 ~ 1.4769	0.9191 ~ 0.9245	0.3 ~ 1.7	187.3 ~ 196.4	113.3 ~ 143.2	0.97 ~ 1.79

TABLE 8. PROPERTIES OF THE OILS CONTAINED IN VARIOUS BLUBBERS AND MEATS OF BLACK RIGHT WHALE C

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Blubber of hind part	58.98	1.4735	0.9208	0.7	193.1	124.6	1.08
of blow-hole	55.66	1.4735	0.9219	0.3	192.8	122.4	0.89
,,							
Middle back meat	68.46	1.4760	0.9193	0.5	189.7	135.3	0.73
,,	65.33	1.4715	0.9180	0.8	189.4	133.3	1.11
,,	70.80	1.4720	0.9201	0.4	188.5	137.5	0.85
Posterior back meat	60.37	1.4765	0.9227	1.3	192.6	127.6	0.94
,,	64.78	1.4751	0.9205	1.7	193.2	129.1	0.78
Thoracic blubber	46.47	1.4740	0.9211	0.5	195.0	119.9	1.06
,,	45.69	1.4733	0.9203	0.4	193.7	124.6	0.81
,,	44.62	1.4722	0.9225	0.9	195.2	122.8	0.96
Anterior abdominal blubber	63.52	1.4749	0.9208	0.4	188.3	137.5	0.85
,,	60.31	1.4725	0.9223	0.4	190.4	133.2	0.97
Blubber of fore part of genital aperture	72.42	1.4743	0.9238	0.8	189.3	138.5	1.12
,,	70.97	1.4754	0.9225	0.6	188.5	136.2	0.79
,,	69.12	1.4736	0.9227	0.5	187.1	140.9	0.84
Tail flucks blubber	40.58	1.4753	0.9211	0.5	196.2	119.2	0.83
,,	44.42	1.4745	0.9206	0.4	194.1	125.0	0.97
,,	42.71	1.4740	0.9227	0.8	196.0	117.4	1.03
,,	39.53	1.4729	0.9201	0.9	193.9	123.6	0.69
Thoracic meat	0.80	1.4731	0.9192	0.9	190.6	133.1	1.28

TABLE 9. PROPERTIES OF THE OILS CONTAINED IN VARIOUS ORGANS OF BLACK RIGHT WHALE C

Parts	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Oesophagus	13.07	1.4736	0.9197	0.6	193.7	125.9	1.11
,,	12.39	1.4721	0.9208	0.8	192.9	128.4	1.02
Stomach	6.98	1.4744	0.9245	0.9	194.1	124.4	1.15
Large Intestine	7.21	1.4754	0.9233	0.5	191.0	129.5	1.37
,,	7.98	1.4763	0.9221	0.7	190.7	131.5	1.19
,,	6.18	1.4760	0.9246	0.9	191.5	127.3	1.30
Liver	11.52	1.4749	0.9208	0.5	190.2	134.9	1.82
,,	13.73	1.4745	0.9227	0.8	189.9	131.5	1.48
,,	11.04	1.4729	0.9236	0.6	190.6	132.4	1.68
Heart	2.87	1.4753	0.9196	1.2	194.6	122.2	1.56
,,	2.36	1.4738	0.9209	1.0	192.9	120.8	1.39
Spine	4.03	1.4751	0.9248	0.7	194.6	122.9	1.61
Kidney	6.97	1.4740	0.9233	0.5	190.9	132.4	1.31
,,	8.19	1.4754	0.9218	0.5	191.4	133.5	1.19
Bladder	12.88	1.4732	0.9228	0.3	194.1	125.3	0.73
Testicle	9.02	1.4762	0.9209	1.9	195.7	117.1	1.06
,,	7.21	1.4738	0.9211	1.7	196.4	119.7	1.29
Epididymis	2.28	1.4761	0.9241	0.6	194.6	122.3	1.27

TABLE 10. PROPERTIES OF THE OILS OF BLACK RIGHT WHALE C

Kind of oils	Oil content (%)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Blubber oils (19 samples)	39.33 ~ 72.42	1.4715 ~ 1.4765	0.9180 ~ 0.9255	0.3 ~ 1.7	187.1 ~ 196.2	117.4 ~ 140.9	0.96 ~ 1.12
Meat oil (1 sample)	0.80	1.4731	0.9192	0.9	190.6	133.1	1.28
Organ oils (18 samples)	2.36 ~ 13.73	1.4721 ~ 1.4763	0.9196 ~ 0.9248	0.3 ~ 1.9	189.9 ~ 196.4	117.1 ~ 134.9	0.73 ~ 1.82

TABLE 11. PROPERTIES OF THE OIL CONTAINED IN MIDDLE BACK BLUBBER OF BLACK RIGHT WHALE C

Appearance (15°C.)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Light yellowish orange, opaque cohesive liquid	1.4760	0.9193	0.5	189.7	135.3	0.73

II

The oil contained in middle back blubber of the black right whale C (Table 1) was prepared by boiling the material with water and refined with a centrifugal separator. Chemical characteristics of the obtained oil are shown in Table 11.

Next, to some 200 g. of the sample oil was added 200 c.c. of absolute alcohol and further potassium hydroxide solution (KOH 87 g. and H_2O 148 c.c.) and heated in an atmosphere of nitrogen gas for two hours on a water bath, after which the majority of ethanol was distilled off and the resulting soap solution was cooled and diluted with water. It is preferable to risk the chance of slightly imcomplete saponification rather than to incur the rearrangement of some of the highly unsaturated components. The unsaponifiable material was removed from the soap solution with ethyl-ether, and 190 g. of the conjugated fatty acids were recovered after decomposing the soap solution with 10% sulfuric acid solution.

180 g. of the mixed fatty acids (I.V. 148.3) thus recovered was subjected to the lead-salt alcohol separation method as modified by Hilditch,[8] whereupon 49.32 g. of solid fatty acids (I.V. 9.4) and 130.68 g. of liquid fatty acids (I.V. 199.2) were obtained.

120 g. of the liquid fatty acids was then subjected to the lithium-salt acetone separation method,[9] when 84.96 g. of lowly unsaturated fatty acids (I.V. 153.3) and 35.04 g. of highly unsaturated fatty acids (I.V. 305.5) were obtained.

Finally, the total mixed acids consist of 27.4% solid acids, 51.4% lowly unsaturated acids and 21.2% highly unsaturated acids.

Each group of the fatty acids (solid, lowly unsaturated and highly unsaturated) was separately converted into methyl esters by the usual method[10]. Some properties of the fatty acids and methyl esters are shown in Table 12.

TABLE 12. PROPERTIES OF FATTY ACIDS AND THEIR METHYL ESTERS (MIDDLE BACK BLUBBER OIL)

Fatty acids	%	Neuter. value	Iodine value	Methyl esters	
				Sapon. value	Iodine value
Mixed fatty acids	—	199.1	148.3	—	—
Solid fatty acids	27.4	205.9	9.4	196.1	8.5
Lowly unsaturated fatty acids	51.4	198.6	153.3	190.1	149.2
Highly unsaturated fatty acids	21.2	186.5	305.5	178.4	299.8

Each ester was fractionated as usual through E.H.P. column modified by Tsuyuki.[11] The iodine value and saponification value of each of the subfractions of all the groups of methyl esters were determined in the usual manner. The most unsaturated fraction, HU, was taken up first without any loss of time, then the less unsaturated fraction LU, and lastly the least unsaturated fraction S. The ester-fractionation date, along with the saponification values and iodine values, are given in Tables 13～15.

The composition of each of the ester fractions was caluculated from the saponification values and iodine values according to the method described by

Hilditch.[12] The mean unsaturation expressed as the fractional number of hydrogen atoms short of saturation, for example, −2.0 H (monoethenoid), was determined by the usual method. The component acids in three ester fractions are given in Table 16 along with the final fatty acids composition of the original oil calculated from these figures (Fig. 3).

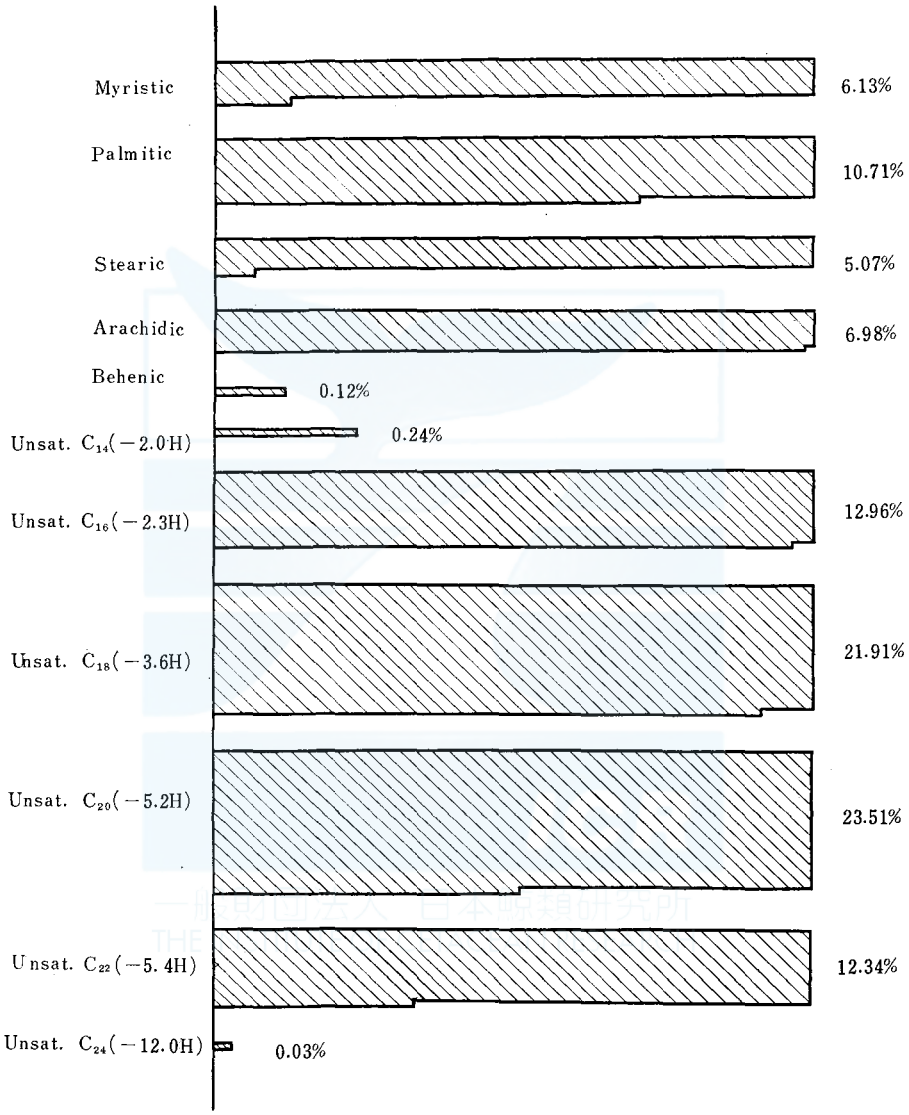

Fig. 3. Calculated composition of total acids in middle back blubber oil of black right whale C

III

The oil contained in spine of the black right whale C was extracted with acetone

in an atmosphere of nitrogen gas. Chemical properties of the obtained oil (acetone -soluble lipid) are given in Table 17.

TABLE 13. FRACTIONAL DISTILLATION OF METHYL ESTERS OF SOLID FATTY ACIDS

Fraction	g.	%	Boiling point (°C/3.5 mmHg)	Sapon. value	Iodine value
S—1	2.18	14.55	—148	218.7	0.6
S—2	2.03	13.51	148—154	212.4	1.5
S—3	2.17	14.52	154—160	208.5	2.7
S—4	2.29	15.23	160—170	193.1	3.8
S—5	1.86	12.42	170—190	185.3	7.9
S—6	1.74	11.59	190—195	179.7	10.8
S—7	1.83	12.16	195—	174.1	24.1
S—8	0.90	6.02	Residue	170.1	33.2
Total	15.00	100.00			

TABLE 14. FRACTIONAL DISTILLATION OF METHYL ESTERS OF LOWLY UNSATURATED FATTY ACIDS

Fraction	g.	%	Boiling point (°C/2mmHg)	Sapon. value	Iodine value
LU— 1	2.97	9.91	—146	212.3	79.7
LU— 2	2.82	9.41	146—154	208.7	92.2
LU— 3	2.05	6.82	154—156	199.4	114.4
LU— 4	3.13	10.43	156—158	197.5	135.5
LU— 5	3.53	11.75	158—160	192.2	148.2
LU— 6	2.84	9.46	160—163	188.8	160.8
LU— 7	2.52	8.40	163—166	185.1	168.1
LU— 8	2.72	9.06	166—171	179.4	176.3
LU— 9	1.79	9.30	171—175	176.5	182.8
LU—10	1.73	5.78	175—180	175.1	186.2
LU—11	1.34	4.47	180—185	172.4	189.2
LU—12	1.08	3.59	185—	170.2	193.4
LU—13	0.48	1.62	Residue	167.8	198.2
Total	30.00	100.00			

TABLE 15. FRACTIONAL DISTILLATION OF METHYL ESTERS OF HIGHLY UNSATURATED FATTY ACIDS

Fraction	g.	%	Boiling point (°C/1mmHg)	Sapon. value	Iodine value
HU—1	2.28	15.21	—175	199.2	232.1
HU—2	2.56	17.06	175—185	189.0	271.3
HU—3	3.87	25.81	185—192	174.1	298.7
HU—4	3.36	22.40	192—200	166.2	326.8
HU—5	1.53	10.21	200—207	165.5	356.5
HU—6	0.90	5.98	207—	163.4	388.1
HU—7	0.50	3.30	Residue	162.2	235.4
Total	15.00	100.00			

TABLE 16. COMPOSITION OF FATTY ACIDS OF MIDDLE BACK BLUBBER OIL OF BLACK RIGHT WHALE C

Acids	Solid fatty acids (27.40%)	Lowly unsaturated fatty acids (51.40%)	Highly unsaturated fatty acids (21.20%)	Total (100%)
Saturated acid:				29.01
Myristic	2.17	3.96	—	6.13
Palmitic	10.38	0.33	—	10.71
Stearic	4.80	0.27	—	5.07
Arachidic	6.98	—	—	6.98
Behenic	0.12	—	—	0.12
Unsaturated acids:				70.99
C_{14}	—	0.24(-2.0H)	—	0.24(- 2.0H)
C_{16}	0.24(-2.0H)	11.57(-2.2H)	1.15(-2.7H)	12.96(- 2.3H)
C_{18}	0.55(-2.0)	16.66(-4.0H)	4.70(-5.7H)	21.91(- 3.6H)
C_{20}	2.01(-2.0H)	15.61(-4.2H)	5.89(-7.9H)	23.51(- 5.2H)
C_{22}	0.51(-2.0H)	2.76(-5.6H)	9.43(-9.1H)	12.34(- 5.4H)
C_{24}	—	—	0.03(-12.0H)	0.03(-12.0H)

TABLE 17. PROPERTIES OF THE OIL CONTAINED IN SPINE OF BLACK RIGHT WHALE C

Appearance (15°C)	n_D^{20}	d_4^{15}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Light brownish yellow, non-opaque cohesive liquid	1.4751	0.9248	0.7	194.6	122.9	1.61

To the samle oil was added a minimum quantity of potassium hydroxide (44 g. per 100 g. of the oil) dissolved in alcohol solution (absolute alcohol 100 c.c. and H_2O 80 c.c. per 100 g. of the oil) and heated for two hours on a water bath, after which nearly 80% of alcohol was distilled off and the resulting soap solution was cooled and diluted with water. The unsaponifiable material was removed from the soap solution with ethyl-ether, and the mixed fatty acids were recovered after decomosing the soap solution with 10% sulfuric acid solution. The mixed acids obtained were resolved into different fractions according to varying degrees of unsaturation, first by the lead-salt alcohol method modified by Hilditch,[8] and then by the lithium-salt acetone method.[9]

Finally, three groups of the fatty acids (solid, lowly unsaturated, highly unsaturated acids) were obtained. The total fatty acids consist of 30% solid acids, 46.8% lowly unsaturated acids and 23.2% highly unsaturated acids. Each group of the fatty acids was separately converted into methyl esters taking the precautions suggested by Hilditch.[10] Some characteristics of the fatty acids and their methyl esters are summarized in Table 18.

Each group of the methyl esters was fractionated through the same column[11] as described in II. The iodine value and saponification value of each of the subfractions were determined, and the data are given in Table 19~21.

The composition of each of the ester fractions was calculated from the saponifi-

TABLE 18. PROPERTIES OF FATTY ACIDS AND THEIR METHYL ESTERS (SPINE OIL)

Acids	%	Neutr. value	Iodine value	Methyl ester	
				Sapon. value	Iodine value
Mixed fatty acids	—	203.2	136.2	—	—
Solid fatty acids	30.0	214.4	8.3	203.1	7.6
Lowly unsaturated fatty acids	46.8	200.3	132.1	191.4	127.8
Highly Unsaturated fatty acids	23.2	188.7	300.6	180.4	295.1

cation values and iodine values by the method of Hilditch.[12] The component acids in the ester fractions are shown in Table 22 along with the composition of the original oil calculated from these figures (Fig. 4).

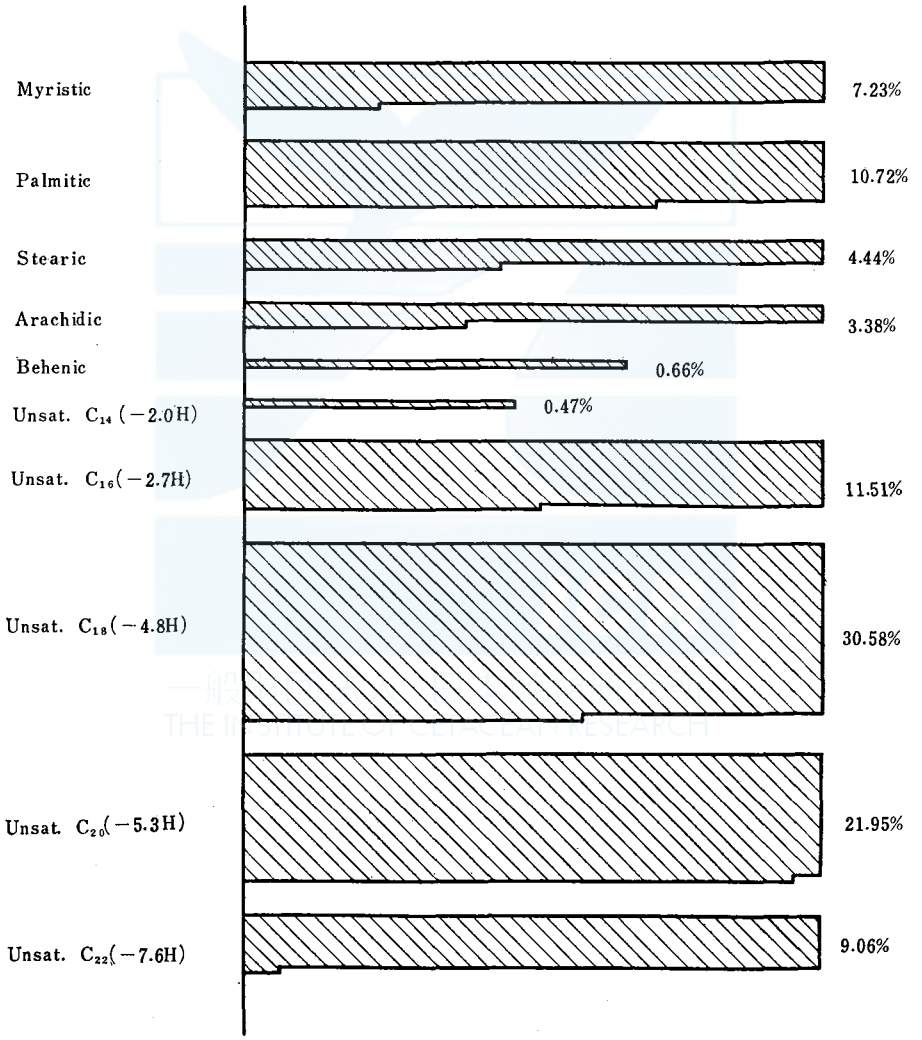

Fig. 4. Calculated composition of total acids in spine oil of black right whale C

DISCUSSION

The properties of some blubber oils of a black right whale caught in 1956 were studied by Dr. Saiki[6] and the results are shown in Table 23. The differences between the Saiki's results and the writer's results in this work on the properties of the blubber oils of the black right whale are not clear.

The properties of various baleen whale oils studied by many workers are shown in Table 24 in order to discuss the differences in the properties of the black right whale oil and other baleen whale oils.

From Table 2~10, in the properties of the oils contained in the black right whale bodies, the individual difference can not be found clearly. The reason seems to be due to that the above three whales are almost same not only in sex but also in living circumstance and age. The differences in the properties of the oils contained in various parts of each whale body were comparatively clear, but the regularities can't be observed in this differences.

TABLE 19. FRACTIONAL DISTILLATION OF METHYL ESTERS OF SOLID FATTY ACIDS (SPINE OIL)

Fractions	g.	%	Boiling point (°C/3.5mmHg)	Sapon. value	Iodine value
S—1	2.42	16.12	—147	227.1	0.4
S—2	2.57	17.13	147—153	223.4	1.2
S—3	3.02	20.16	153—165	216.7	3.0
S—4	2.43	16.22	165—180	194.3	5.3
S—5	2.40	16.01	180—196	181.6	11.6
S—6	1.55	10.31	196—	175.9	20.8
S—7	0.61	4.05	Residue	168.2	32.6
Total	15.00	100.00			

TABLE 20. FRACTIONAL DISTILLATION OF METHYL ESTERS OF LOWLY UNSATURATED FATTY ACIDS (SPINE OIL)

Fractions	g.	%	Boiling point (°C/2mmHg)	Sapon. value	Iodine value
LU— 1	2.61	8.69	—145	212.9	63.2
LU— 2	2.84	9.48	145—155	209.3	77.9
LU— 3	3.17	10.56	155—160	199.7	94.8
LU— 4	3.30	11.02	160—164	194.5	112.2
LU— 5	3.64	12.14	164—168	190.9	131.5
LU— 6	4.01	13.35	168—172	187.8	142.1
LU— 7	2.91	9.70	172—177	183.0	157.6
LU— 8	1.87	6.23	177—182	178.9	162.9
LU— 9	2.47	8.23	182—187	177.6	166.8
LU—10	2.55	8.49	187—	174.7	170.3
LU—11	0.63	2.11	Residue	170.3	174.5
Total	30.00	100.00			

TABLE 21. FRACTIONAL DISTILLATION OF METHYL ESTERS OF HIGHLY UNSATURATED FATTY ACIDS (SPINE OIL)

Fractions	g.	%	Boiling point (°C/1mmHg)	Sapon. value	Iodine value
HU—1	2.12	14.15	—180	203.4	212.3
HU—2	1.98	13.17	180—190	191.6	265.3
HU—3	3.01	20.04	190—200	181.0	310.1
HU—4	4.68	31.21	200—210	171.1	339.5
HU—5	1.90	12.68	210—	170.7	362.2
HU—6	1.31	8.75	Residue	168.3	206.7
Total	15.00	100.00			

TABLE 22. COMPOSITION OF FATTY ACIDS OF SPINE OIL OF BLACK RIGHT WHALE C

Acids	Solid fatty acids (30.0%)	Lowly unsaturated fatty acids (46.8%)	Highly unsaturated fatty acids (23.2%)	Total (100%)
Saturated acids:				26.43
Myristic	6.82	0.41	—	7.23
Palmitic	8.82	1.90	—	10.72
Stearic	3.16	1.28	—	4.44
Arachidic	3.38	—	—	3.38
Behenic	0.66	—	—	0.66
Unsaturated acids:				73.57
C_{14}	—	0.47(-2.0H)	—	0.47(-2.0H)
C_{16}	2.28	8.27(-2.0H)	0.36(-3.6H)	11.51(-2.7H)
C_{18}	2.76	21.21(-4.3H)	6.61(-6.1H)	30.58(-4.8H)
C_{20}	1.36	11.64(-4.6H)	8.95(-8.3H)	21.95(-5.3H)
C_{22}	0.62	1.62(-7.6H)	7.28(-9.0H)	9.06(-7.6H)

TABLE 23. PROPERTIES OF BLUBBER OILS OF BLACK RIGHT WHALE
(Dr. M. Saiki)

Part	Oil content (%)	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)
Anterior abdominal blubber	60.6	0.98	189.7	141.2	0.68
Abdominal blubber	54.3	1.90	191.3	129.2	0.83
Middle back blubber	69.7	0.94	190.5	140.9	0.81
Blubber of fore part of genital aperture	74.1	0.61	187.9	142.7	1.23
Posterior back blubber	65.1	0.86	187.1	138.8	0.80
Umbilicus blubber	59.4	1.01	189.0	130.9	0.85
Range	54.3 ~ 74.1	0.61 ~ 1.90	187.1 ~ 191.8	129.2 ~ 142.7	0.68 ~ 1.23

TABLE 24. PROPERTIES OF VARIOUS BALEEN WHALE OILS

Kind of oils	d_4^{15}	n_D^{20}	Acid value	Sapon. value	Iodine value	Unsapon. material content (%)	Remark
Black right whale							
Blubber oil	0.9175~0.9259	1.4697~1.4768	0.1~1.7	187.1~169.2	116.9~143.7	0.55~1.27	
Meat oil	0.9190~0.9259	1.4730~1.4738	0.9~1.9	190.6~193.5	126.3~133.1	0.99~1.28	Tsuyuki, Naruse,
Viscerous oil	0.9189~0.9251	1.4700~1.4769	0.2~2.2	187.3~196.4	113.3~143.2	0.73~1.82	
Bone oil			0.6~1.0	187.1~191.8	129.2~142.7	0.68~1.23	Saiki
Fin whale							
Blubber oil	0.9137~0.9236	1.4705~1.4769	0.4~4.5	190.3~200.0	95.2~155.8	0.32~1.98	
Tongue oil	0.9200~0.9222	1.4711~1.4750	0.5~1.2	193.3~200.7	93.6~110.7		Toyama, Uozaki
Viscerous oil	0.9225~0.9250	1.4736~1.4761	0.5~0.9	191.5~200.0	109.2~134.3		Tsujimoto, Tanimura
Bone oil	0.9150~0.9219	1.4694~1.4724	0.6~5.0	195.1~200.0	82.7~110.0		Saiki *et al*
Blue whale							
Blubber oil	0.9208~0.9222	1.4700~1.4726	0.5~2.1	192.8~200.0	100.0~110.0	1.0~2.0	
Tongue oil	0.9200~0.9260	1.4700~1.4800	0.5~1.0	190.0~195.2	100.0~110.0	1.0~2.0	
Viscerous oil	0.9200~0.9265	1.4685~1.4750	0.8~5.0	190.0~195.0	68.0~110.0	1.0~2.0	Tsujimoto
Bone oil	0.9250~0.9254	1.4700~1.4727	0.4~1.0	190.0~195.0	100.0~110.0		Ueno, Iwai *et al*
Meat oil		1.4648	0.4	194.3	122.3		
Head blubber oil		1.4640	0.4	198.2	116.3		
Humpback whale							
Blubber oil	0.9154~0.9234	1.4690~1.4772	0.3~1.5	183.5~195.2	100.0~159.4	0.31~1.09	
Meat oil		1.4763	0.7	195.5	134.1	※ 0.68	Ueno, Iwai
Viscerous oil	0.9200~0.9217	1.4650~1.4737	0.3~5.0	190.0~195.2	113.5~126.4	1.00 2.00	Tsujimoto
Tongue oil	0.9175~0.9200	1.4700~1.4706	0.2~1.0	189.2~190.0	90.0~100.0		Toyama, Uozaki *et al*
Bone oil	0.9176~0.9251	1.4700~1.4735	0.5~6.1	187.7~192.9	98.9~110.0	1.00~2.00	
Head blubber oil		1.4663	0.3	195.5	130.7	0.89	
Sei whale							
Blubber oil	0.9150~0.9250	1.4700~1.4785	0.2~3.3	181.5~193.1	115.0~161.5	0.56~2.70	Ueno, Tanimura
Tongue oil	0.9150~0.9211	1.4700~1.4735	0.5~2.0	190.0~200.0	90.6~115.0	1.00~2.00	Toyama, Uozaki
Bone oil	0.9202~0.9400	1.4737~1.4753	11.3~16.4	190.0~200.0	108.3~121.7	1.00~2.00	Saiki *et al*
Viscerous oil	0.9250~0.9276	1.4700~1.4702	0.5~5.0	190.0~190.7	90.0~ 90.7	1.00~2.00	
Grey whale							
Blubber oil	0.9250~0.9280	1.4767~1.4800	0.5~3.0	190.0~192.7	134.2~150.0	1.86~2.00	
Viscerous oil	0.9300~0.9330	1.4780~1.4800	0.5~5.0	190.0~195.9	140.0~155.0	1.00~2.00	Ueno *et al*
Bone oil	0.9300~0.9350	1.4750~1.4800	0.5~7.0	190.0~195.0	130.0~150.0	1.00~2.00	

Appearance Color of the black right whale oils, generally, was dark and light yellow, or dark and light yellowish orange. However, color of the viscera oils rarely was brown or brownish red. Color of the blubber oils is more fainter than that of the viscera oils. The viscosity of the sample oils is different accordingly to the parts of the whale body.

Oil content Oil content in the blubbers is very high. For example, the oil content in the blubber of " Dendō " of the whale A is the lowest (32.62%), whilst that in the blubber of fore part of genital aperture of the whale A is the highest (73.80%). The oil content in the back blubber and in the blubber of fore part of genital aperture is comparatively high with the range of 60~70%. On the contrary, the oil content in the thoracic blubber, " Dendō " blubber and tail fluckes blubber is rather low with about 40%, respectively. The oil content in the back meat and thoracic meat is very low with the range of 0.68~0.93%, though many material meats were not obtained. The oil content in the viscera is lower than that in the blubbers, but higher than that in the meats. For example, the oil content in the heart of the whale C is 2.36% and that in the tongue of the whale B is 31.85%. The oil content in the lung and tongue is comparatively high with the range of 25~30%, whilst the oil content in the heart is about 2% and that in the epididymis and spine is 3~4% respectively and that in these three samples is very low.

Refractive index Refractive index of various black right whale oils is different accordingly to the parts of the whale body. However, the regurality is unable to be seen in the difference of refractive index of various sample oils. Observing the refractive index of the sample oils at 20°C, that of the blubber oils is from 1.4697 to 1.4768, that of the meat oils is from 1.4730 to 1.4738 and that of the viscera oil from 1.4700 to 1.4760.

Specific gravity Specific gravity of the sample oils is different with the parts of the whale body. But the writers can't find the reguralities in the difference of specific gravity of the sample oils. Observing the specific gravity of the sample oils at 15°C, the range of specific gravity is from 0.9175 to 0.9259 in the case of the blubber oils, 0.9190 to 0.9259 in that of the meat oils and 0.9189 to 0.9251 in that of the viscera oils.

Acid value Acid value of the sample oils is generally low, being considered to be from 0.1 to 1.7 in the case of the blubber oils, 0.9 to 1.9 in that of the meat oils and 0.2 to 2.2 in that of the viscera oils. If the authors dare to discuss the difference in the acid value of the sample oils, the acid value of the former oil is lower than that of the latter two oils. The reason why the acid value of the sample oils is generally low seems to be as follows: As the materials had been refrigerated in the range of −20~−30°C., the decomposition of the oils in the materials with lipase and the rancidity of the oils in the materials with oxygen had not almost been

happened.

Saponification value The authors can not find the regurality in the differences of the saponification values of the blubber oils, meat oils and viscera oils. The saponificationn value is 187.1 to 196.2 in the case of the blubber oils, 190.6 to 193.5 in that of the meat oils and 187.3 to 196.4 in that of the viscera oils.

Iodine value The writers can not find the regurality in the differences of the iodine values of the blubber oils, meat oils and viscera oils. The iodine value is in the range of 113.9～143.7 in the case of the blubber oils, 126.3～133.3 in that of the meat oils and 113.3～143.2 in that of the viscera oils. If the authors dare to discuss the differences in these iodine values, the blubber oils with lower iodine value were the tail fluckes blubber oil (117～125), posterior back blubber oil (122～130) and thoracic blubber oil (120～125). The viscera oils with lower iodine value were testicle oil (110～120), epididymis oil (116～122), stomach oil (123～130) and tongue oil (113～116). Whilst the blubber oils with higher iodine value were the middle back blubber oil (133～144), anterior abdominal blubber oil (130～141) and the blubber oil of fore part of genital aperture (134～143). The viscera oils with higher iodine value were the small intestine oil (136～143) and lung oil (133～137).

Unsaponifiable material content As to the unsaponifiable material content (%) in the black right whale oil, that of the blubber oils were 0.55 to 1.27, meat oils 0.99 to 1.28% and viscera oils 0.73 to 1.83%. If the authors dare to discuss the differences in the unsaponifiable material content of various sample oils, the content of the blubber oils is lower than that of the meat oils and viscera oils. Considering of the unsaponifiable material content, it seems that the content of the black right whale oil is essentialy different with that of the toothed whale oil such as the sperm whale oil and is similar to the baleen whale oil such as the fin whale oil. The relation of the characteristics of the black right whale oil and those of other baleen whale oils are shown in Table 24. Being shown in Table 24, the unsaturation of the oil of the black right whale caught in the Northern Pacific Ocean seems to be higher than that of the oils of the fin whale, blue whale, humpback whale and sei whale caught in the Antarctic Ocean. Because, the unsaturation of the oil contained in *Calanus*[13] which is the diet of whales in the Northern Pacific Ocean is higher than that of the oil contained in *Euphausiacea* which is the diet of whales in the Antarctic Ocean. Dr. Saiki[13] had mentioned that the difference between the unsaturation of the oils of the whales in the Northern Pacific Ocean and that of the oils of the whales in the Antarctic Ocean seems to be due to the diet. The authors also think that the diet of the whale effects to the characteristics of the whale oils. The unsaturation of the black right whale oil seems to be higher than that of other baleen whale oils, but is lower than that of the grey whale oil.

Saponification value of the black right whale oil is lower than that of the fin whale oil and blue whale oil, and is near to that of the humpback whale oil and

grey whale oil.

The unsaponifiable material content in the black right whale oil is near to that in the fin whale oil and humpback whale oil, and is lower than that of the blue whale oil, sei whale oil and grey whale oil.

That the acid value of the sample oils in the present work is generally lower, seems to depend on that the rancidity of the oil with oxygen and decomposition of the oils with lipase had hardly been occured because of keeping the materials in such low temperature as $-20\sim-30°C$.

Component fatty acids The two sample oils, the middle back blubber oil and the spine oil, from the black right whale C, had iodine values 135.3 and 122.9, respectively. This difference in their unsaturation is somewhat clear when the writers compare the component fatty acids of the two oils (Tables 16 and 22).

The fatty acid composition of the middle back blubber oil is shown in Table 16 and Fig. 3. It is noticed that the total saturated fatty acid content is 29.01% (myristic acid $C_{13}H_{27}COOH$: 6.13%, palmitic acid $C_{15}H_{31}COOH$: 10.71%, stearic acid $C_{17}H_{35}COOH$: 5.07%, arachidic acid $C_{19}H_{39}COOH$: 6.98%, behenic acid $C_{21}H_{43}COOH$: 0.12%) of the total. The unsaturated fatty acid content is 70.99% (C_{14} acids: 0.24%, C_{16} acids: 12.96%, C_{18} acids: 21.91%, C_{20} acids: 23.51%, C_{22} acids: 12.34%, C_{24} acid: 0.03%) of the total. In this case, the degree of unsaturation are as follows: C_{14} acid: $-2.0H$, C_{16} acids: $-2.3H$, C_{18} acids: -3.6 H, C_{20} acids: $-5.2H$, C_{22} acids: $-5.4H$, C_{24} acid: $-12.0H$. The chief component acids belong to the unsaturated C_{20} series (23.51%), the next most prominent are those of the unsaturated C_{18} series (21.91%), unsaturated C_{16} series (12.96%), unsaturated C_{22} series (12.34%) and plamitic acid (10.71%). Whilst the saturated acids including myristic (6.13%), stearic (5.07%) and arachidic (6.98%) are present in somewhat lower proportions. Behenic acid (0.12%), unsaturated C_{14} acid (0.24%) and unsaturated C_{24} acids (0.03%) are trace.

On the other hand, the fatty acid composition of the spine oil is given in Table 22 and Fig. 4. It is noticed that the total saturated fatty acid content is 26.43% (myristic acid: 7.23%, palmitic acid: 10.72%, stearic acids: 4.44%, arachidic acid: 3.38%, behenic acid: 0.66%) of the total. The unsaturated counterpart is 73.57% {C_{14} acid ($-2.0H$): 0.47%, C_{16} series ($-2.7H$): 11.51%, C_{18} series ($-4.8H$): 30.58%, C_{20} series ($-5.3H$): 21.95%, C_{22} series ($-7.6H$): 9.06%} of the total. The component acids of the spine oil studied by the writers show the following tendency: The chief component acids belong to the unsaturated C_{18} series (more than 30%) and the next prominant is the unsaturated C_{20} series (about 22%). The next component acids are those of the unsaturated C_{16} series (11.51%), palmitic acid (10.72%), the unsaturated C_{22} series (9.06%) and myristic acid (7.23%), whilst the saturated acids such as stearic and arachidic are $3\sim5$% respectively and behenic acid is less than 1%.

The saturated fatty acid content (%) was lower in the case of the spine oil

than in that of the middle back blubber oil, and on the other hand the unsaturated acid content (%) was higher in the case of the former oil than in that of the latter oil. However, the highly unsaturated fatty acid content was rather lower in the case of the former oil than in that of the latter oil. Therefore, the former oil seems to contain a large amount of the lowly unsaturated fatty acids consisted mainly of C_{18} series. In the case of the spine oil, the total of the unsaturated C_{18} series (more than 30%) and C_{20} series (about 22%) is nearly 52%. Whilst in the case of the middle back blubber oil, the total of the unsaturated C_{20} series (about 24%) and C_{18} series (about 22%) is about 46%. It is remarkable that the content (%) of the unsaturated C_{18}' series which is the main component acid of the spine oil is very high (more than 30%). In spite of that the middle back blubber oil contains the unsaturated C_{24} acid (−12.0H) tracely, the spine oil seems to not contain the unsaturated C_{24} series at all.

Considering that the saturated fatty acid content in the fish oils is generally about 20%, that in the black right whale oil is about 30% and nearly 10% higher than that in the fish oils. Generally, in the case of the component fatty acids of the fish oils, the content (%) of the unsaturated C_{22} and C_{24} series are respectively rather high. Therefore, comparing the component fatty acids of the black right whale oil with those of the fish oils, it seems that the unsaturated C_{22} series content is somewhat lower and the unsaturated C_{24} series content is much lower in the case of the former oil than in that of the latter oil.

Reviwing the report (Drs. Saiki and Mori[13]) studied on the component fatty acids of the oil contained in *Calanus cristatus* obtained from the stomach of the fin whale caught in the Northern Pacific Ocean, it was noticed that the total saturated fatty acid content is about 16% (myristic: 9%, palmitic: 7%, stearic: trace) and the total unsaturated fatty acid content is about 84% {C_{14}(−2.0H) acid: 3%, C_{16}(−2.2H) series: 10%, C_{18}(−4.7H) series: 14%, C_{20}(−4.2H) series: 29%, C_{22}(more than −4.2H) series: 38%}. From the result mentioned above, it is notable that the saturated fatty acid content is only 16%. *Calanus plumchrus*[7] was contained in the stomach of three black right whales in this work. The authors presume that the properties of the oil contained in *Calanus plumchrus* are near to the properties of *Calanus cristatus* oil. Thinking that the component fatty acids of the black right whale oil contain 30% saturated acids, it seems that the saturated acids are contained in larger amount in the case of the black right whale oil than in that of *Calanus plumchrus* oil.

SUMMARY

1) Chemical properties of the oils contained in various parts of three black right whales, *Eubalaena glacialis*, caught in the Northern Pacific Ocean were studied. The results obtained are as follows:

[Blubber oil] d^{15}_4: 0.9175∼0.9259, n^{20}_D: 1.4697∼1.4768, Acid value: 0.1∼1.7, Saponification value: 187.1∼196.2, Iodine value: 116.9∼143.7, Unsaponifiable material content: 0.55∼1.27%.

[Meat oil] d^{15}_4; 0.9190～0.9259, n_D^{20}: 1.5730～1.4738, Acid value: 0.9～1.9, Saponification value: 190.6～193.5, Unsaponifiable material content: 0.99～1.28%.

[Viscera oil] d^{15}_4: 0.9189～0.9251, n_D^{20}: 1.4700～1.4769, Acid value: 0.2～2.2, Saponification value: 187.3～196.4, Iodine value: 113～143.2, Unsaponifiable material content: 0.73～1.82%.

2) Middle back blubber oil from the black right whale contains 29.01% saturated fatty acids (myristic: 6.13%, palmitic: 10.71%, stearic: 5.07%, arachidic: 6.98%, behenic: 0.12%) and 70.99% unsaturated fatty acids {C_{14}(−2.0H): 0.24%, C_{16}(−2.3H): 12.96%, C_{18}(−3.6H): 21.91%, C_{20}(−5.2H): 23.51%, C_{22}(−5.4H): 12.34%, C_{24}(−12.0H): 0.03%} of the total.

3) Spine oil (acetone- soluble) from the black right whale contains 26.43% saturated acids (myristic: 7.23%, palmitic: 10.72%, stearic: 4.44%, arachidic: 3.38%, behenic: 0.66%) and 73.57% unsaturated acids {C_{14}(−2.0H): 0.47%, C_{16}(−2.7H): 11.51%, C_{18}(−4.8H): 30.58%, C_{20}(−5.3H): 21.95%, C_{22}(−7.6H): 9.06%} of the total.

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