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PRELIMINARY USE OF NEAR-INFRARED SPECTROSCOPY TO ESTIMATE THE BIOCHEMICAL COMPONENTS OF THE MUSCLES OF THE ANTARCTIC MINKE WHALE *BALAENOPTERA BONAERENSIS*

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Abstract

The energetic condition of whales is an important information to understand their energy demand to sustain their migration and reproductive success. However, basic energetic information based on biochemical components (protein, lipid, sugar, and water) and calorimetric data are limited, particularly in small baleen whales such as the minke whale. This study reports the biochemical components of the muscle tissues of 61 Antarctic minke whales (*Balaenoptera bonaerensis*) of different sexes and sexual maturity using near-infrared (NIR) spectroscopy. Prior to sample analysis, a calibration curve based on a standard chemical analysis was installed in the NIR analytical equipment. The dorsal muscle tissues from Antarctic minke whales contain approximately 0.5%–0.6% lipid, 26% protein, and 73% water, suggesting that the dorsal muscle contains a small amount of lipid and a high proportion of water. These proportions were similar between sexes and sexual classes. The proportions of lipids in the dorsal muscle of Antarctic minke whales are likely to be lower than those of other baleen whales, such as sei (*B. borealis*) and fin (*B. physalus*) whales, and this requires further investigation.

Key words: lipid contents, nutritional condition, muscle tissue, Antarctic minke whale.

The information about the nutritional indices of baleen whales is important to evaluate their energetic conditions and energy demand to sustain their migration and reproductive success. The information on their biochemical components, such as protein, lipid, sugar, and water, and calorimetric data are necessary to estimate the total energy deposit of individuals and evaluate their nutritional indices. The biochemical components of large whales, such as fin (*Balaenoptera physalus*) and sei (*B. borealis*) whales, were previously reported (Arai and Sakai, 1952; Lockyer *et al.*, 1984, 1985; Aguilar and Borrell, 1990).

This biochemical composition differs among whale species, and it also varies with the season, body size, reproductive status, and organs (Lockyer *et al.*, 1984, 1985; Aguilar and Borrell, 1990). Therefore, species-specific biochemical information is needed to estimate their energy deposits using tissues that function as a lipid deposit. However, little information is available for Antarctic minke whales (*B. bonaerensis*). The biochemical components and lipid contents of Antarctic minke whales were previously reported from the aspect of food nutrition (Ito *et al.*, 1993, 1998; Iida *et al.*, 1998). The biochemical components of the "red meat" from three Antarctic minke whales (a mature male, an immature female, and a >30-year-old female) were reported by Iida *et al.* (1998). The lipid contents of the dorsal muscle at the level of the dorsal fin (regarded as red meat) and tail (regarded as lipid-rich "tail meat") were examined in 29 males and 23 females (Ito *et al.*, 1998). Although fat tissue such as blubber function as lipid deposit, muscle mass represents a greater proportion in terms of weight

Fig. 1. Near-infrared spectrometer CA-HM (Joy World Pacific Co. ltd.) and a terminal PC. The solid muscle samples were homogenized using a food processor and a portion the (approximately 25 g) was set for analysis on a saucer at the lower right slot.

(Gunnlaugsson *et al.*, 2020). Therefore, it is important to determine the biochemical components of their muscle tissues to calculate the total energy contents and their function for energy storage.

In this study, near-infrared (NIR) spectroscopy was used to determine the biochemical components of the muscle tissues of Antarctic minke whales. While conventional methods analyze the samples only for a single component, NIR spectroscopy allows simultaneous measurements of multiple biochemical components, optimizing the use of samples. However, this NIR technique needs a calibration based on a regression model to predict the biochemical properties based on spectral data (Prieto *et al.*, 2017).

The NIR technique was used to estimate the biochemical components of the muscle tissues from 61 Antarctic minke whales sampled during the austral summer of 2016/17 under NEWREP-A (New Scientific Whale Research Program in the Antarctic Ocean). Muscle tissues were sampled from the dorsolateral muscle at the level of the dorsal fin. To reduce the seasonal effect on the analyses of the biochemical components during the summer feeding period, the samples from a limited time period in the survey season were used (December 15–January 5). The samples involved 25 immature males, 14 mature males, 17 immature females, and five pregnant females.

The muscle samples were scanned using an NIR spectrometer, CA-HM (Joy World Pacific Co., Ltd.; Fig. 1). Before the analysis, a calibration curve set for whale muscles was prepared (Fig. 2). This figure shows the plots of the values of protein, lipid, and water components from conventional chemical analyses and NIR spectroscopy. The muscle tissues from Antarctic minke whales and North Pacific sei whales were used for this calibration. This calibration curve was fit using these values and installed in the spectrometer.

The muscle samples were homogenized using a food processor, and a sub-sample (approximately 25 g) was set on a saucer dedicated for NIR spectroscopy (Fig. 3). In both conventional chemical analyses and NIR spectroscopy, the white fibrous parts, such as perimysium, were not removed from the muscle sample since these are muscle components. However, the results were expected to vary slightly by homogenizing the muscle samples.

The summary of the NIR analysis of the dorsal muscle at the level of the dorsal fin of Antarctic

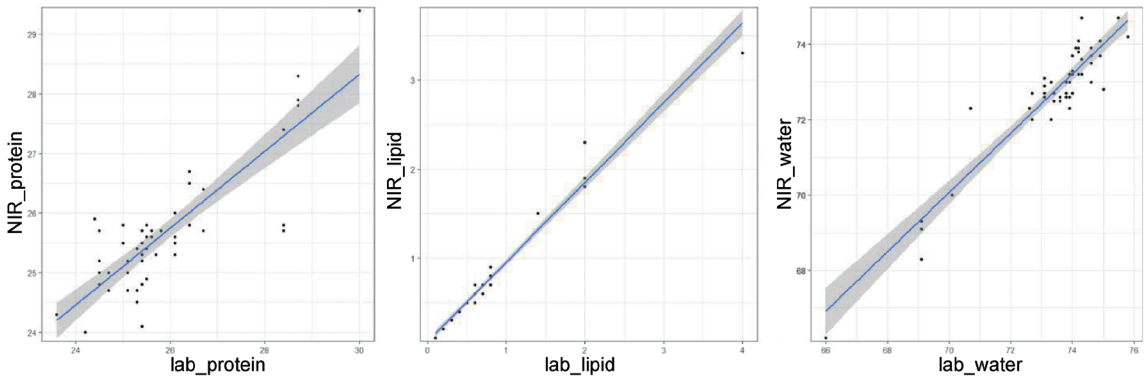

Fig. 2. Comparisons of biochemical components between laboratory-based and near-infrared (NIR) analyses to set a standard curve of the whale muscles for NIR spectroscopy. Left, protein; center, lipid; right, water. The muscle samples from Antarctic minke and North Pacific sei whales were used. The gray bands represent the 95% confidence intervals.

Fig. 3. Homogenized muscle of an Antarctic minke whale set on a saucer before analysis on the near-infrared spectrometer. The white fibrous parts were included in the analysis.

minke whales is listed in Table 1. On average, the muscle tissues contain approximately 0.5%–0.6% lipid, 26% protein, and 73% water, showing that the muscle consists of a very small amount of lipid and a high percentage of water in all maturity stages. The lipid compositions are similar among sexes and sexual maturity/classes. The results of Iida *et al.* (1998) are similar to the results of this study (Table 1). Ito *et al.* (1998) also showed that the lipid content of the dorsal muscle at the level of the dorsal fin was approximately 1.1% in Antarctic minke whales sampled in the austral summer of 1990/91 (Table 1). This lipid content in muscle tissues was slightly higher compared to the results of the present study. However, the energy storage differs among years and seasons (Konishi *et al.*, 2008; Konishi and

Table 1. Summary of the calorie content and biochemical components (per 100 g) of the muscles of Antarctic minke whales. For comparative purposes, the data from the results of Iida *et al.* (1998) and Ito *et al.* (1998) based on conventional analyses are also indicated.

	Immature male		Mature male		Immature female		Pregnant female		Iida *et al.* (1998)			Ito *et al.* (1998)			
	mean	SD	mean	SD	mean	SD	mean	SD	Mature male	Immature female	Mature female	Male	SD	Female	SD
Calorie (kcal)	106.03	3.54	107.05	6.22	104.18	2.28	107.61	3.33	—	—	—	—	—	—	—
Protein (g)	25.08	0.45	25.58	0.82	24.82	0.35	25.45	0.47	24.10	24.00	24.40	—	—	—	—
Lipid (g)	0.59	0.22	0.48	0.37	0.50	0.15	0.60	0.17	0.70	0.30	0.36	1.14	0.57	1.11	0.5
Sugar (g)	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.15	0.36	0.14	—	—	—	—
Water (g)	73.23	0.63	72.84	1.13	73.58	0.43	72.85	0.63	74.40	74.60	74.50	—	—	—	—
Ash	—	—	—	—	—	—	—	—	0.92	1.65	0.90	—	—	—	—
Lateral blubber thickness at the level of dorsal fin (cm)	3.33	0.61	3.41	0.44	3.22	0.47	3.10	0.66	—	—	—	—	—	—	—
Half girth at the level of umbilicus (cm)	163.28	18.27	212.00	10.70	166.29	19.14	214.20	9.91	—	—	—	—	—	—	—
Sample size	25		14		17		5		1	1	1	29		23	

Walløe, 2015), and this difference may suggest a possible seasonal and yearly variation of lipid contents in the muscles of Antarctic minke whales.

The lipid contents of the dorsal muscles of fin and sei whales exceeded 3% on average. The muscles in the anterior body part at the level of the flippers have less accumulated lipids compared to those in the middle and posterior parts of the body (Lockyer *et al.*, 1985). Given this, the muscles of Antarctic minke whales seem to have less lipid contents than those of large baleen whales. However, to confirm this, further comparative analyses among baleen whale species should be conducted using the same methodology while strictly considering the body parts from where the muscle samples are obtained.

The application of NIR spectroscopy to estimate the biochemical components of whale tissues is useful and practical to determine the basic information about the energetics of baleen whales. The use of techniques, such as NIR, which allows analysis of multiple components from a single sample, is of particular utility in the case of baleen whale samples, which are limited and difficult to access.

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