Insights into the Calorimetric Analysis of Shark Livers

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Introduction

Very little work has been done on studying the caloric content of a major energy storage organ in many fish, the liver. Most fish store their energy reserves in either the liver or in muscle tissue. For example, Bratland et al. (1976) show that cod and pollack among other species, store their primary energy reserves in the liver, as fat. This is apparently true for many sharks also, although specific information is scarce. Since the liver is a major storage organ its condition or the amount of fat reserves present can indicate something of the organism's condition or recent environmental or physiological history. For example, recent reproduction, accessability of food or general health of the fish may be indicated from the condition of the liver.

Very little has been done with examining the caloric content of shark liver or in developing a liver index (a ratio of total liver weight to total body weight) or a condition index. This study was started to gain insight into the caloric content of the livers of three species of sharks and to use these measurements to attempt to develop a condition indices that can be compared to the liver index. The utilization of the liver index as a measure of the condition of a fish is useful only for fishes which store their fat reserves in the liver, i.e. Gadidae, sharks and rays (cited in Jensen, 1979). Our study indicated an increase in liver index reflects a storage of lipids in the liver evidenced by increased caloric values. Shark liver tissue which we analyzed showed significant variability as seen in the range of mean caloric values of 4276-7556 cal/g wet weight.

Methods

Liver samples from three species of sharks (sandbar, Carcharhinus milberti, blue, Prionace glauca and mako, Isurus oxyrinchus) were collected during March 1980. The sampling area extended from 30 to 135 miles east of Daytona Beach, Florida, northward along the western margin of the Gulf Stream to 50 miles northeast of Cape Hatteras. The sandbar sharks were generally collected off Jacksonville, Florida, the other species generally off Cape Hatteras. Twenty-six shark liver samples were collected from these three species. The fork length, body weight and liver weight for each shark specimen supplying a liver sample are recorded in Table 1. Subsamples of each liver, weighing approximately 225 gm, were taken from each specimen and frozen for analysis. To prepare these subsamples for analyses, they were chopped and homogenized in a commercial blender. To determine moisture content subsamples of homogenate of each liver sample were dried in an oven at 106-110°C for 4 to 5 hours. Examination of the dried samples using a moisture balance showed only approximately 0.1% residual moisture after oven drying. This drying process was repeated a second time as a confidence check on the procedure. The second drying resulted in closely related values. The greatest variation between two matching moisture content values was 16% but in most cases it was 5%, or less.

For determination of ash content, portions of the frozen homogenate were burned in a muffle furnace at 500°C for 5 hours and reweighed. Calcium carbonate, $CaCO_3$, content was determined by reburning the ash sample at 900°C after reweighing. The calorimetric determinations were accomplished with a Parr 1241 adiabatic calorimeter, following suggested methodology (Parr 1970). Initially, an attempt was made to dry samples of the frozen homogenate using a vacuum dryer, but some of the liquid oil fraction of the sample spattered under the vacuum.

In our successful first method results were obtained by changing the drying procedure to air drying the samples in a silica gel desicator for 4-5 hours. A second weighing of each sample after drying showed an average moisture loss of 1 to 5 per cent. Separation of the oil fraction and solid matter was usually evident. These "wet" samples, contained in combustion crucibles, were then tested for caloric content following standard combustion methods (Parr 1970). In each case, a sample weighing between 0.5 and 1.5 grams was used. Placement of fuse wire was found to be very critical; greatest success was obtained when the fuse wire was allowed to just slightly touch the sample at the surface of the liquid oil fraction of the sample. Calculated caloric values were expressed as Calories per °C/gm wet weight. Corrections for acid production and endothermic reactions within the bomb were omitted because these were expected to be insignificant at the sample size used and the low ash and $CaCO_3$ contents observed ($\bar{<}$ 1%) (Paine 1971; Schroeder 1977).

Finally, a second method was tried which consisted of taking subsamples from each of the shark livers weighed into combustion crucibles and dryed in an oven at 100°C for 5 hours. Moisture content was determined after reweighing yielding values ranging from 30-40%. These crucibles containing dry shark liver were used in calorimetric determinations which resulted in a mean value of 9037 cal/°C/g dry weight.

Results

The results of the "wet" weight determinations of this study are presented in Table 2. This table also presents a liver index, based on a ratio of total liver weight to total body weight, of each specimen, and the mean caloric equivalent value of replicate determinations for each liver specimen. The mean caloric equivalency of sandbar shark liver was highest (6850 cal/g dry wt) with a range of 6536-7556 cal/g dry wt. The mako shark's liver had a mean caloric equivalency value of 5760 cal/g dry wt and range of 5108-7379 cal/g dry wt and the blue shark the lowest mean caloric equivalency, 5012 cal/g dry wt with a range of 3493-7262 cal/g dry wt.

The liver index for each species follows the same pattern with sandbar having highest mean index of 9.9 and the blue shark with the lowest 4.5, with mako intermediate at 6.3.

The alternate second method tried, that we believe produces a caloric determination on a dry weight basis, indicated a value of 8572 cal/°C/g dry weight for blue shark and 9524 cal/°C/g dry weight for sandbar and 9015 (mako).

Table 1. The fork length, total body and liver weight of three species of sharks collected off Jacksonville, Florida and off Cape Hatteras, NC.

Species	Spec. #	Fork Length (cm)	Total Body Wt. (kg)	Total Liver Wt. (kg)
Carcharhinus milberti	2	140	31.0	2.789
	3	131	28.0	2.781
	12	120	21.0	1.682
	22	135	31.5	3.162
	25	142	33.0	3.894
	26	126	23.0	1.924
	27	122	21.5	1.719
	29	136	30.0	3.541
	30	136	35.0	3.422
	31	136	28.5	3.471
Prionace glauca	47	248	108.0	3.255
	104	227	86.0	3.606
	109	220	78.0	3.061
	110	205	58.0	3.906
	111	172	39.0	2.184
	124	207	61.0	1.968
	125	206	60.0	2.901
	126	193	61.0	2.571
	127	196	47.0	2.139
	136	199	56.0	2.102
Isurus oxyrinchus	112	187	74.0	4.135
	114	184	65.0	2.823
	116	158	44.0	1.788
	119	225	117.0	7.120
	147	139	31.0	4.250
	149	174	65.0	2.529

Table 2. The liver index $\left(\frac{\text{wt. of liver x 100}}{\text{wt. of fish}}\right)$ and caloric equivalency of three species of shark.

Species and Specimen #		Liver sample wt. gm	Liver Index	# of burns	Caloric value cal/°C/g wet wt.	Standard Deviation
Carcharhinus milberti	2	226	9.0	4	6911	± 49.12
	3	227	10.0	3	7242	± 222.22
	12	229	8.0	5	5759	± 285.57
	22	227	10.0	5	6536	± 73.56
	25	233	12.0	5	7106	± 148.60
	26	226	8.0	5	6681	± 106.09
	27	227	8.0	5	6696	± 99.79
	29	227	12.0	4	7556	± 152.48
	30	229	10.0	4	6713	± 81.70
	31	227	12.0	5	7297	± 114.52
			$\bar{x}$ = 9.9		$\bar{x}$ 6850	
Prionace glauca	47	223	3.0	5	3493	± 183.14
	104	227	4.0	5	5008	± 55.09
	109	219	4.0	3	4947	± 118.22
	110	221	7.0	5	7262	± 159.76
	111	228	6.0	5	6137	± 161.08
	124	218	3.0	3	3637	± 266.68
	125	228	5.0	3	5675	± 201.64
	126	224	4.0	5	5051	± 123.28
	127	220	5.0	3	4633	± 233.59
	136	230	4.0	3	4276	± 150.11
			$\bar{x}$ = 4.5		$\bar{x}$ 5012	
Isurus oxyrinchus	112	219	6.0	4	5271	± 325.04
	114	222	4.0	3	5535	± 60.93
	116	222	4.0	3	7379	± 433.00
	119	220	6.0	4	6015	± 260.78
	147	220	14.0	4	5108	± 358.09
	149	221	4.0	3	5257	± 219.00
			$\bar{x}$ = 6.3		$\bar{x}$ 5760	

Discussion and Conclusions

The apparently high lipid content of shark liver tissue caused us to significantly modify the suggested methodology to produce caloric determinations in which we felt we could have some confidence. The problem with the high lipid content was the difficulty in extracting water from the sample or determine the water content without losing organic material. The first method tried which produced a "wet" value we feel is less preferred because of the above water content problem. The second method, the dry method, would appear to hold more promise for this type of tissue.

The four values determined by the second method, 8572-9524 cal/g dry wt., are very close to the value (9450 cal/g dry wt) found in pollack liver oil (Jensen 1979).

The usefulness of using the caloric content of shark livers as a condition index based on this more or less preliminary examination is still unanswered. Jangaard et al. (1967) has found that the liver lipid contents of cod to range from 15 to 75% and there were significant sexual differences. The wide range of values found for individual specimens (Table 2) also allude to this variability. It is of interest however, that the mean values (on a "wet" wt. basis) show a pattern positively related to liver index and perhaps to the ecological niche of the species, i.e. the demersal sandbar shark had highest liver index and liver caloric value and the two pelagic species the lowest.

It is suggested that the calorimetry be supplemented by biochemical analysis based on the findings of Beukema and DeBruin (1979).

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