NPAFC
Doc. 615
Rev.

Total Lipid Contents in the White Muscle, Liver, and Gonad of Chum Salmon Caught in the Bering Sea and the Gulf of Alaska in Summer 2001

By

Tetsuichi Nomura[1], Masa-aki Fukuwaka[2], Nancy Davis[3]

and Morihiko Kawana[1]

[1] *National Salmon Resources Center. Nakanoshima 2-2, Toyohira-ku, Sapporo, 062-0922 Japan.*

[2] *Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro, Hokkaido, 085-0822 Japan*

[3] *School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020 USA*

Submitted to the

NORTH PACIFIC ANADROMOUS FISH COMMISSION

By

JAPAN

October 2002

This paper may be cited in the following manner:

Nomura, T., M. Fukuwaka N. Davis and M. Kawana. 2002. Total lipid contents in the white muscle, liver, and gonad of chum salmon caught in the Bering Sea and the Gulf of Alaska in summer 2001. (NPAFC Doc. 615) 12 pages. National Salmon Resources Center. Toyohira-ku, Sapporo 062-0922, Japan.

Total Lipid Contents in the White Muscle, Liver, and Gonad of Chum Salmon Caught in the Bering Sea and the Gulf of Alaska in Summer 2001

Tetsuichi Nomura[1], Masa-aki Fukuwaka[2], Nancy Davis[3] and Morihiko Kawana[1]

[1] *National Salmon Resources Center. Nakanoshima 2-2, Toyohira-ku, Sapporo, 062-0922 Japan.*

[2] *Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Katsurakoi 116, Kushiro, Hokkaido, 085-0822 Japan*

[3] *School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020 USA*

Abstract

Generally, it is assumed that salmon in the ocean consume heavily in the summer and, therefore, the lipid level in the muscle of these fish may be higher than in spring and winter. This study is the first to report the total lipid (TL) content in the white muscle, liver, and gonad of chum salmon by age group from fish caught in the international waters of the Bering Sea and Gulf of Alaska. The TL was extracted from the muscle of 336 chum salmon using chloroform and methanol and then measured gravimetrically. Younger fish (ocean age-.1) had significantly lower TL than older fish (ocean age-.2, -.3, -.4 and -.5). In the Bering Sea, the average TL in the muscle of ocean age-.1 female and male fish was 3.4% (n=15) and 3.3% (n=16),

respectively. The TL contained in older chum salmon ranged from 8.9% (females, age-.2) to 12.1% (females, age-.5). The average TL content in muscle, liver, and gonad obtained from analysis of round samples of ocean age-.1 female fish (n=12) was 3.0%, 6.1%, and 2.7%, respectively. The average TL in the muscle and liver of male fish (n=11) was 2.5% and 4.8%, respectively. In the Gulf of Alaska, the average TL in ocean age-.1 females was 5.1% (n=3) and males was 4.6% (n=7). For ocean age-.2 chum salmon, average TL was 9.9% in females (n=22) and 8.8% in males (n=15). Low lipid content in young chum salmon in summer may indicate the summer is the time for fish growth at the expense of lipid storage, whereas the fall my be a time when lipid is stored at the expense of growth in order to promote survival through a lean winter. We recommend continuing the study of chum salmon TL content by age group with an emphasis on monitoring seasonal changes, particularly those that occur in the fall.

Introduction

The quantity of lipid has been used as a biochemical index of trophic condition for freshwater and marine fish (Novotony and Beeman 1990). Dietary lipids play an important role in providing energy in carnivorous fish like salmonids due to their limited ability to utilize carbohydrates as an energy source (Watanabe 1982). Although there have been a large number of lipid studies on cultured fish and artificial food (Wilson 1991), little is known about high-seas salmonid lipid

content. Azuma et al. (1998) reported on the growth characteristics of Pacific salmon by examination of triglycerol and protein content, and nucleic acid ratios. In previous papers, total lipid (TL) content and fatty acid composition were used to investigate trophic condition of chum and pink salmon in the North Pacific Ocean in winter (Nomura et al. 2000) and in spring (Nomura et al. 2001). A low lipid content in the muscle and a high percentage of docosahexaenoic acid (DHA) in the fatty acid composition of neutral lipid were observed in chum and pink salmon in winter. A low lipid content in white muscle also was observed in ocean age-.1 and age-.2 fish in the Gulf of Alaska in spring 1999. Information on the lipid content of salmonids during high-seas migrations can be used to estimate their trophic condition and growth. In general, it is assumed that salmonids consume prey heavily during the summer, and, therefore, the lipid content in the muscle would be higher in the summer than in spring and winter. This study is the first to report the TL content in the white muscle, liver, and gonad of chum salmon by age group from fish caught in the summertime from the international waters of the Bering Sea and Gulf of Alaska.

Materials and Methods

Chum salmon were caught by surface drift gillnets during the summer 2001 cruises of the R/V *Wakatake-maru* in the Bering Sea and T/V *Oshoro-maru* in the Gulf of Alaska (Tables 1 and 2). Fork length (FL, cm) and body weight (BW, g) of chum salmon were measured onboard the vessels, and salmon age was determined by examination of

scale patterns. Tissues were collected from 336 chum salmon: 250 samples of dorsal muscle collected directly behind the head and 25 round samples collected from the Bering Sea, and 61 fish fillets collected from the Gulf of Alaska. The samples were kept frozen at –30°C until analyzed. The TL in the white muscle was extracted with chloroform and methanol following the method of Folch et al. (1957). In the first step, the lipids were extracted by homogenizing the white muscle (10 g), liver (5g), or ovary (5g) with 50 ml of methanol and 120 ml of chloroform. The gonad of male fish was not analyzed, because TL content of the testes is low. The homogenate was filtered through a lipid-free paper into a glass vessel. The crude extract and water were mixed in a separator funnel in the proportions 8:4:3 by volume. The lower phase was collected, and the solvent was evaporated with a rotary evaporator. In the final step, the TL content was measured gravimetrically.

Results

Bering Sea

The TL in female and male age-.1 chum salmon was low, and older male and female (ocean age-.2, -.3, -.4, and -.5) had significantly higher TL than younger fish (Table 3, Fig. 1). The average TL in the muscle of ocean age-.1 female and male fish was 3.4% (n=15) and 3.3% (n=16), respectively. The TL contained in older fish ranged from 8.9% (females, age.-2) to 12.1% (females age-.5). There was no significant difference in TL between female and male fish among all

age groups ($p > 0.05$), and no significant difference in TL and gonadosomatic index in female and male fish ($p > 0.05$, Fig.2). Age could not be determined for eight chum salmon.

The TL in the muscle, liver, and gonad was determined from round samples of 25 fish (Table 4). The average TL content in muscle, liver, and gonad of ocean age-.1 female fish (n=12) was 3.0%, 6.1%, and 2.7%, respectively. The average TL in the muscle and liver of male fish (n=11) was 2.5% and 4.8%, respectively.

Gulf of Alaska

The average TL was 5.1% in age-.1 females (n=3) and 4.6% in age-.1 males (n=7; Table 5). For ocean age-.2 chum salmon, average TL was 9.9% in females (n=22) and 8.8% in males (n=15).

Discussion

The effect of the fish's age must be taken into consideration when examining lipid levels in salmon in offshore waters (Nomura et al. 2000, Nomura et al. 2001). In this study, we found a statistically significant difference in the TL of white muscle among ocean age groups of chum salmon caught in the summertime in the Bering Sea and in the Gulf of Alaska, where TL increases significantly as the fish ages.

Our results indicate that TL of chum salmon increased in summer, even in the youngest (ocean age-.1) fish (Tables 3, 4 and 5). In summer, young (ocean age-.1) chum salmon in both ocean regions had lower lipid levels than older salmon, but the starved condition observed

in winter and spring (winter TL=1.1% and spring TL=1.4% in female and 1.2% in male) by Nomura et al. (2000, 2001) does not appear to continue in the summer.

Our results cannot explain the reason for the observed lower lipid content of young chum salmon as compared with older fish in summer. During their ocean migrations salmon use energy for movement, metabolism, and growth. Low lipid content in young chum salmon indicates either inadequate intake of dietary lipid, or utilization of their lipid for growth, or a combination of these two conditions. It is possible that the expenditure of energy for growth, takes priority over lipid storage in the summer. However, immediately prior to the onset of winter a negative correlation between triacylglycerol (storage lipid; a highly concentrated store of metabolic energy) content and the RNA:DNA ratio indicates juvenile (ocean age-.0) chum salmon slow their growth rate to maintain energy reserves (Azuma et al. 1998). Low lipid content in young chum salmon in summer may indicate the summer is the time for fish growth at the expense of lipid storage, whereas the fall my be a time when lipid is stored at the expense of growth in order to promote survival through a lean winter. Food availability in the late summer and fall, particularly for young fish, may be critical to survival through the following winter. We recommend continuing the study of chum salmon TL content by age group with an emphasis on monitoring seasonal changes, particularly those that occur in the fall.

Acknowledgements

We express our appreciation to the captain, officers and crew of the R/V *Wakatake-maru* and T/V *Oshoro-maru* for their help in collecting samples during our research cruises.

References

Azuma, T., T. Yada, Y. Ueno, and M. Iwata. 1998. Biochemical approach to assessing growth characteristics in salmonids. N. Pac. Anadr. Fish Comm. Bull., 1: 103-111.

Folch, A.J., M. Lees, and G.H. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226: 497-509.

Nomura, T., S. Urawa, and Y. Ueno. 2000. Variations in muscle lipid content of high-seas chum and pink salmon in winter. N. Pac. Anadr. Fish Comm. Bull., 2: 347-352.

Nomura, T., K.W. Myers, C.M. Kondzela, J.M. Murphy, H. Honma, and H.R. Carlson. 2001. Variation in lipid content in the muscle of chum and pink salmon in the Gulf of Alaska in May 1999. Bull. Nat. Salmon Res. Ctr., 4, 13-18.

Novotony, J.F., and J.W. Beeman. 1990. Use of a fish health condition profile in assessing the health and condition of juvenile chinook salmon. Prog. Fish-Cult., 52: 162-170.

Watanabe, T. 1982. Lipid nutrition in fish. Comp. Biochem. Physiol. B, 73: 3-75.

Wilson, R. P. 1991. Handbook of nutrient requirement of finfish. CRC Press, London. 196 p.

Table 1. Sampling station, location, date, and number of chum salmon sampled in the Bering Sea during summer, 2001.

Station	Latitude	Longitude	Date	No. of Fish
18	55º30´N	180º00´	July 2	50
19	56º30´N	180º00´	July 3	50
21	58º30´N	180º00´	July 5	50
24	56º30´N	178º00´E	July 8	50
24	56º30´N	178º00´E	July 8	25[1]
28	56º30´N	177º00´W	July 12	50
Total				275

[1]Round sample for lipid content analysis of muscle, liver, and gonad

Table 2. Sampling station, location, date, and number of chum salmon sampled in the Gulf of Alaska during summer, 2001.

Station	Latitude	Longitude	Date	No. of Fish
4	56º01´N	145º02´W	July 1	1
5	54º59´N	145º01´W	July 2	13
6	53º59´N	145º01´W	July 3	12
7	52º59´N	144º59´W	July 4	5
8	51º59´N	144º59´W	July 4	7
9	50º00´N	145º00´W	July 8	23
Total				61

Table 3. Mean and standard deviation in parenthesis of fork length (FL), body weight (BW), and total lipid (TL) content in the white muscle of chum salmon caught in the Bering Sea during summer, 2001.

Ocean Age	Sex	Number of Fish	FL (cm)	BW (g)	TL (%)
1	Female	15	34.1 (2.1)	391 (74.6)	3.4 (1.70)
	Male	16	46.9 (3.4)	418 (148.9)	3.3 (1.18)
2	Female	21	48.2 (3.5)	1,235 (29.3)	8.9 (4.57)
	Male	22	46.9 (3.4)	1,192 (276.4)	9.7 (4.74)
3	Female	44	55.1 (4.2)	2,075 (516.7)	10.9 (4.07)
	Male	47	56.4 (4.9)	2,390 (783.6)	11.2 (4.19)
4	Female	33	55.1 (4.2)	3,917 (660.4)	10.8 (5.90)
	Male	37	61.8 (5.4)	3,193 (986.1)	11.6 (4.47)
5	Female	3	63.9 (5.2)	3,400 (793.7)	12.1 (5.01)
	Male	4	65.3 (4.0)	3,900 (910.3)	12.0 (2.81)

Table 4. Mean and standard deviation in parenthesis of fork length (FL), body weight (BW), liver weight (LW), gonad weight (GW); and total lipid content in muscle, liver, and gonad of chum salmon caught in the Bering Sea during summer, 2001.

Ocean Age	Sex	No. of Fish	F.L (cm)	BW (g)	LW (g)	GW (g)	Total Lipid Content (%)		
							Muscle	Liver	Gonad
1	Female	12	33.7 (1.83)	451 (81.8)	7.6 (1.65)	1.3 (0.63)	3.0 (0.91)	6.1 (1.43)	2.7 (1.22)
	Male	11	32.7 (3.17)	454 (71.6)	8.3 (2.18)	0.1 (0.01)	2.5 (0.85)	4.8 (0.92)	-
2	Female	1	36.2	617	6.1	3.2	6.1	5.4	3.7
	Male	1	46.5	872	16.9	6.1	3.2	4.3	-

Table 5. Mean and standard deviation in parenthesis of total lipid (TL) content in the white muscle of chum salmon caught in the Gulf of Alaska during summer, 2001.

Ocean Age	Sex	No. of Fish	FL (cm)	BW (g)	TL (%)
1	Female	3	35.9 (0.39)	538 (165.9)	5.1 (5.50)
	Male	7	38.0 (0.53)	603 (289.7)	4.6 (5.76)
2	Female	22	48.8 (2.05)	1351 (183.2)	9.9 (4.14)
	Male	15	50.0 (3.20)	1500 (306.4)	8.8 (4.12)
	Unknown Sex	1	54.2	1800	7.1
3	Female	5	52.3 (3.69)	1711 (646.5)	10.8 (4.34)
	Male	3	52.3 (1.41)	1690 (141.06)	9.8 (1.94)

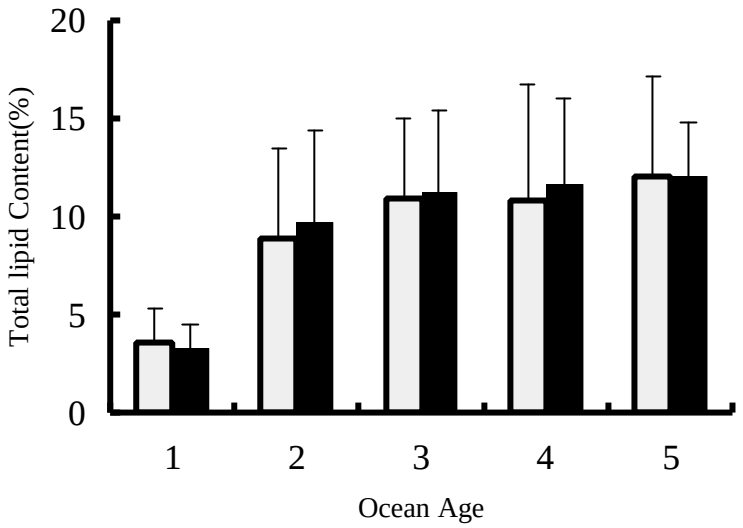

Fig. 1. Total lipid content in the white muscle of chum salmon caught in the Bering Sea by ocean age. Dotted bar and solid bar indicate average of female and male respectively. Line indicates S.D. Sample sizes are shown in Table 1.

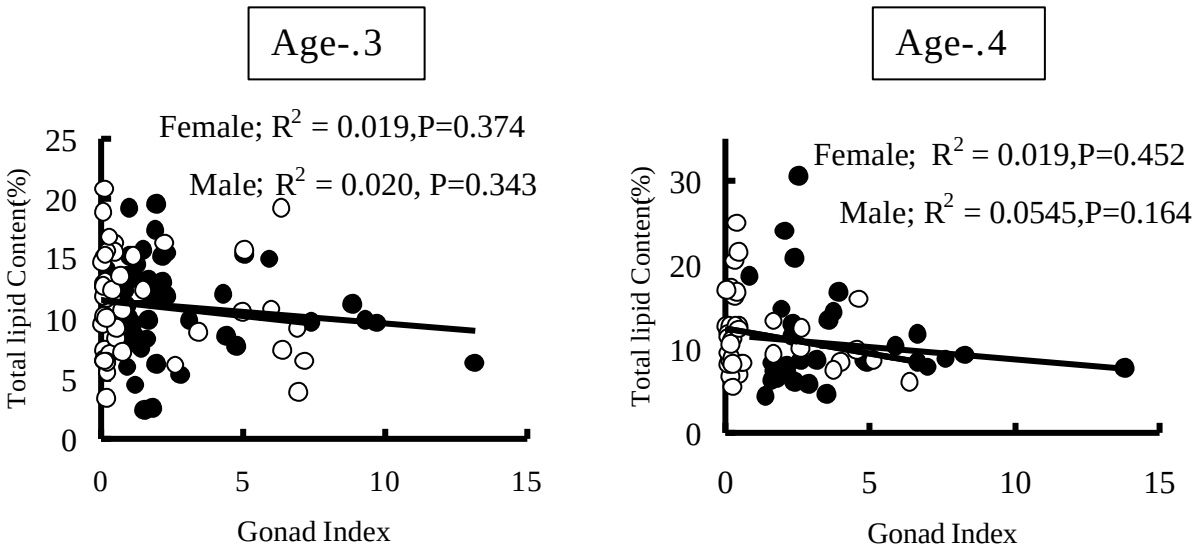

Fig. 2. Relationship between gonad somatic index and total lipid content in the ocean age-.3 and -.4 chum salmon caught in the Bering Sea in 2001. Solid circle; female, open circle; male.