Col.Vol.Sci.Pap. ICCAT, 28 : 196-202 (1988)

FAT, WATER, PROTEIN AND ASH COMPOSITION ON BLUEFIN TUNA COLLECTED IN THE GULF OF ST. LAWRENCE

D. Clay
Gulf Fisheries Center, Department of Fisheries and Oceans
P. O. Box 5030, Moncton, New Brunswick, Canada

SUMMARY

This study shows a very strong relationship between percent fat and percent water in the light colored muscle of bluefin tuna. Fat levels ranged from near zero to 40 percent with a mean of 17 percent, water ranged from near 40 percent to over 80 percent with a mean of 63 percent. These two parameters are related by the equation:

Lipid % = 86.0479 - 1.0953 x water %

The protein and ash composition does not show as wide a range of values as the above and they show little relationship with water or fat. Mean protein levels were 18 percent and ash 0.9 percent. This low level of variation in protein levels with fish of different condition factors indicates tuna obtain the energy required for their extensive northern migration from lipid reserves of the flesh.

RESUME

Cette étude montre une très forte relation entre le pourcentage de lipides et le pourcentage d'eau dans le muscle de couleur pâle du thon rouge. Les niveaux de lipides allaient de zéro à 40 % avec une moyenne de 17 %, alors que l'eau allait de près de 40 à plus de 80 % avec une moyenne de 63 %. Ces deux paramètres sont repris dans l'équation:

% lipides = 86.0479 - 1.0953 x % eau

La composition de protéines et de minéraux ne montrent pas de valeurs avec un écart aussi important que celles ci-dessus et indiquent une faible relation avec l'eau ou les lipides. Les niveaux moyens de protéines s'élevaient à 18 % et les minéraux à 0,9 %. Ce niveau faible de variation dans les niveaux de protéines avec des poissons dont les facteurs de condition sont différents indiquent que les thonidés obtiennent l'énergie nécessaire pour leur longue migration nord à partir des réserves de lipides dans leur peau.

RESUMEN

Este estudio muestra la existencia de una fuerte relación entre el porcentaje de grasa y el de agua en el músculo claro del atún rojo. Los niveles de grasa oscilaron desde cerca de cero al 40%, con una media del 17%, y el contenido en agua varió desde aproximadamente el 40% hasta más del 80%, con una media del 63%. Los dos parámetros se relacionan mediante la ecuación:

Lípidos % = 86.0479 - 1.0953 x % agua

La composición de proteínas y ceniza no muestra una escala de valores tan amplia como la mencionada, e indica escasa relación con líquidos o grasa. Los niveles medios de proteína fueron del 18%, y de ceniza, del 0.9%. La escasa variación en los niveles de proteínas en peces con factores de condición diversa indica que los túnidos obtienen la energía necesaria para su larga migración septentrional de las reservas de lípidos contenidas en su carne.

INTRODUCTION

Many aspects of the life history of bluefin tuna (Thunnus thynnus thynnus, L.) imply a need for large quantities of energy. These include annual migrations over thousands of kilometers, extremely high speed swimming, and the ability to maintain their body temperature at up to 10 °C above ambient. Energy for these activities is generally derived from metabolism of lipids stored in the liver and/or muscles.

The lipid and protein balance is important in assessing the nutritive value of the flesh and as an indicator of seasonal cycles of reproduction and feeding. For bluefin tuna the lipid content is also used as one of the major visual clues in determining price for the lucrative Japanese sashimi market.

Little work, other than that of Braekkan (1956, 1959), has gone into the study of body composition of bluefin and none has been published on the populations of 'giants' in the southern Gulf of St. Lawrence.

This study was conducted to identify the range of values of water, lipid, protein, and ash that might be expected in the population of 'giant' bluefin during their residence in Canadian waters.

MATERIALS AND METHODS

Samples were collected during 1983 and 1984 from 139 Atlantic bluefin landed at commercial fish plants located throughout the southern Gulf of St. Lawrence (Fig 1). The tail section of giant bluefin was removed between the sixth and seventh finlet (to include the 35 th and 36 th vertebrae) as described by Prince and Lee (MS1982). This section corresponds to the point of commercial dressing of the caudal end of the tuna. The tail section was frozen as soon as possible after landing and transported to commercial freezers where temperature was maintained at -20 °C. The samples from 1983 were processed within 6 to 9 months of collection and those of 1984 within 3 to 6 months.

For each fish having valid length and weight data, Fulton's condition factor (Ricker, 1975) was calculated as:

$$(\text{round weight} \times 10^6) \;/\; (\text{fork length}^3).$$

Samples of flesh weighing 2 to 3 g wet weight were removed from the light coloured muscle of the tail section about 3 cm from the exposed cut end and half way between the vertebrae and the outer skin. Three replicate samples were cut from positions separated by about 1 to 2 cm. The replicate samples were placed in a dried 20 ml glass scintillation vial, they were then dried at 75 °C for 48 hours. All weights were to the nearest milligram. Further drying for 96 hours did not reduce the weight. The

Proximate analysis of bluefin

difference in the three replicates from each sample never exceeded 2%. The percent moisture (water) was calculated as:

$$\frac{\text{wet flesh weight} - \text{dry flesh weight}}{\text{wet flesh weight}}$$

The total lipid content was determined by solvent extraction using a method similar to that used by Varga et al. (1977). Each vial with the above dried samples was filled with approximately 15 ml of carbon tetrachloride, left covered for 48 hours and the resultant solution decanted. This was repeated 3 times for each vial. After this procedure the vial was left open over night under a fume hood and then dried at 75 °C for 24 hours. Samples treated in this way and subsequently sent to a commercial analysis laboratory showed residual total lipid levels at between 0.1 and 0.3% of dry weight (equivalent of approximately 0.05 to 0.15% wet weight). Only two samples had replicates differing by more than 1.5% and those differed by less than 2%. The percent lipid (fat) was calculated as:

$$\frac{\text{dry flesh weight} - \text{dry flesh weight (solvent extracted)}}{\text{wet flesh weight}}$$

The protein and ash content were determined from the above solvent extracted samples. Because three replicates were available from each fish, one half of the fish had a replicate ash analysis and a single protein analysis, the other half had replicate protein and a single ash analysis. For the ash content, a dried sample was removed from the vial, weighed and placed in a porcelain crucible which was then put in a muffle furnace heated to a temperature of 450 to 500 °C for 12 to 18 hours (Grodzinski et al., 1975). Most sample replicates varied by less than 0.1% with the remainder varying by less than 0.2%. The percent ash was calculated as:

$$\frac{\text{ash}}{\text{wet flesh weight.}}$$

The percent protein was determined by analyzing Kjeldahl nitrogen content x 6.25. (These analyses were carried out on the dried solvent extracted samples by the Research and Productivity Council of New Brunswick.) The percent protein was adjusted so as to be expressed as the percentage wet weight. All sample replicates for protein analysis varied by less than 1%.

All compositions are expressed as percentage wet weight.

RESULTS & DISCUSSION

The fish ranged in length from 240 cm to 299 cm with a mean length of 275 cm. Due to the migratory pattern of this stock, only giants are available in the Gulf of St. Lawrence and only from July until October. All these fish but one were sampled between August 16 and October 25, the one was accidentally caught on July 19, two weeks before the opening of the season. This small range of length of these fish and short sampling period limits the interpretation of seasonal and size based variation of the body composition. One common feature of most fish species is an annual period of depletion, where energy reserves are drawn down (Love, 1970). Bluefin, as with other scombrids, have a clearly defined seasonal cycle of changing condition factor (Clay et al, MS1985). Despite the short time interval over which samples were collected for this study, this period should include both the 'best and worst' of the seasons' condition factors. This is due to the arrival of the bluefin in Canadian waters in a very poor condition after spawning and their northern migration. During their stay in the Gulf of St. Lawrence these fish are able to gain nearly a kilogram per day (Clay et al., MS1985).

LIPID AND WATER

The mean lipid composition was 17±8% and the mean water composition was 63±7%. An analysis of variance indicated no significant difference ($P > 0.05$) between males and females in the relationship of lipid and water content of the flesh, thus the data for the sexes were combined. The lipid to water relationship is strong (Fig 2) for these bluefin with a coefficient of determination of 0.96. This suggests that the equation could be used with confidence to predict the fat levels of bluefin by a simple and low cost water content analysis. The equation using the mean values for replicates of each fish is:

Lipid % = 86.0429 - 1.0953 x Water % ; r^2=0.96 ; n=93, and

the equation using all analyses (replicates) is:

Lipid % = 85.9899 - 1.0944 x Water % ; r^2=0.95 ; n=279.

The bluefin probably arrive in their poorest condition of the year. This is due to their long post spawning migration from the Gulf of Mexico to northern Canadian waters, the extreme of their geographic range. A weak relationship is observed between percent fat and julian day of sampling (Fig 3) because these fish do not arrive as a single pulse or school and there is no way of knowing how long the fish has been feeding. A similar weak relationship exists between the condition factor and julian day (Fig 4).

Although Love (1970) quoted several sources showing the 'fat-water line' in 'fatty' fish to be linear with the sum of the two 'fairly' constant, the line in this case (Fig 2) does appear to have a slight curvilinear aspect to it. Also, as was noted by Iles and Wood (1965) and Hodder et al. (1973) for herring, the sum of lipid and water composition in bluefin increases as the percent lipid rises (Fig 5, Table 1). The variation is very similar to that observed for herring. Fatty fish store their energy reserves in the musculature while non-fatty fish store it in the liver. The fat-water line of 'fatty' fish is believed to result from these energy reserves being largely in the flesh as opposed to the livers in 'non-fatty' fish.

PROTEIN AND ASH

The mean protein composition was 18±2%. There was no 'protein-water' line (Fig 6) in these bluefin. Protein generally increases with the percent water and inversely with fat levels. Thus although the bluefin are in poor condition when they arrive in the Gulf of St. Lawrence, they must not be in such a state of depletion as to have begun deamination of protein for energy.

The mean ash composition was 0.91±0.21%. Love (1970) stated that ash levels fall when fish are starved or suffering depletion, these bluefin are not therefore under any extreme stress as the ash levels show a positive relationship to water composition (Fig 7) and an inverse relationship to fat.

ACKNOWLEDGEMENTS

Linda Currie and Tom Hurlbut assisted with the sampling, preparation of samples and chemical analysis.

REFERENCES

Clay,D., T.Hurlbut. MS1985 Catch-at-age and estimates of growth of Canadian bluefin tuna. ICCAT Col.Vol.Sci.Pap.XXIV:143-148.

Grodzinski,W., R.Z.Klekowski, and A.Duncan. 1975 Methods for ecological bioenergetics. IBP Handbook No. 24. Blackwell Scientific Publications, London, U.K. pp367.

Hodder,V.M., L.S.Parsons, G.H.Winters and K.Spencer. 1973 Fat and water content of herring in Newfoundland and adjacent waters, 1966-1971. Fish.Res.Board Can., Tech.Rept. 365:49p.

Iles,T.D. and R.J.Wood. 1965 The fat/water relationship in North Sea herring (Clupea harengus), and its possible significance. J. Mar. Biol. Assoc. U.K. 45:353-366.

Love,R.M. 1970 The chemical biology of fishes. Academic Press. London, U.K. pp547.

Prince,E.D. and D.W.Lee. MS1982 Bioprofiles sampling manual for oceanic fishes 1982-83. NOAA Tech. Memo. NMFS-SEFC-103. pp8.

Ricker,W.E. 1975 Computation and interpretation of biological statistics of fish populations. Bull.Fish.Res.Board Can. 191:382p.

Varga,S., G.Sims and T.D.Iles. 1977 The fat and moisture contents of herring populations in the waters of the Canadian maritime provinces. Fish.Mar.Ser.(Canada), Tech.Rept. 723:10p.

--xXx--

Table 1. The lipid plus water composition for various ranges of lipids in the muscles of giant bluefin.

range of lipid	lipid + water	ash	protein
0 - 10 %	79.10 %	1.08 %	19.08 %
10 - 20	79.29	0.94	18.20
20 - 30	81.37	0.83	16.66
30 - 40	83.39	0.76	14.12

Proximate analysis of bluefin

Figure 1. Map of the southern Gulf of St. Lawrence. Sampling locations are marked.

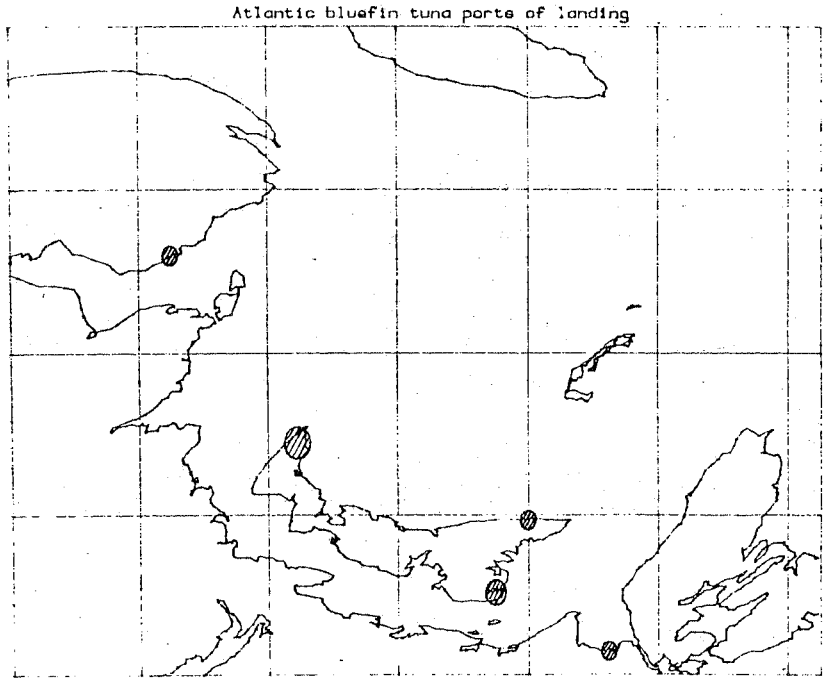

Figure 2. 'Fat-water' line of light coloured muscle of Atlantic bluefin tuna, each symbol represents one of the three replicate samples from a fish.

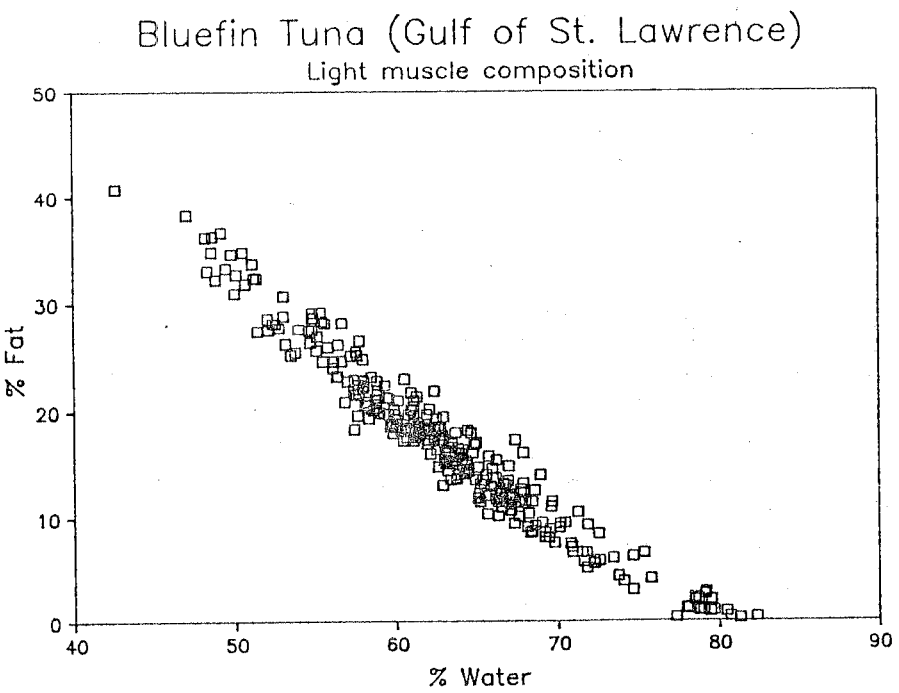

Figure 3. The weak relationship between % fat measured from the light coloured flesh of Atlantic bluefin tuna and julian day of sampling.

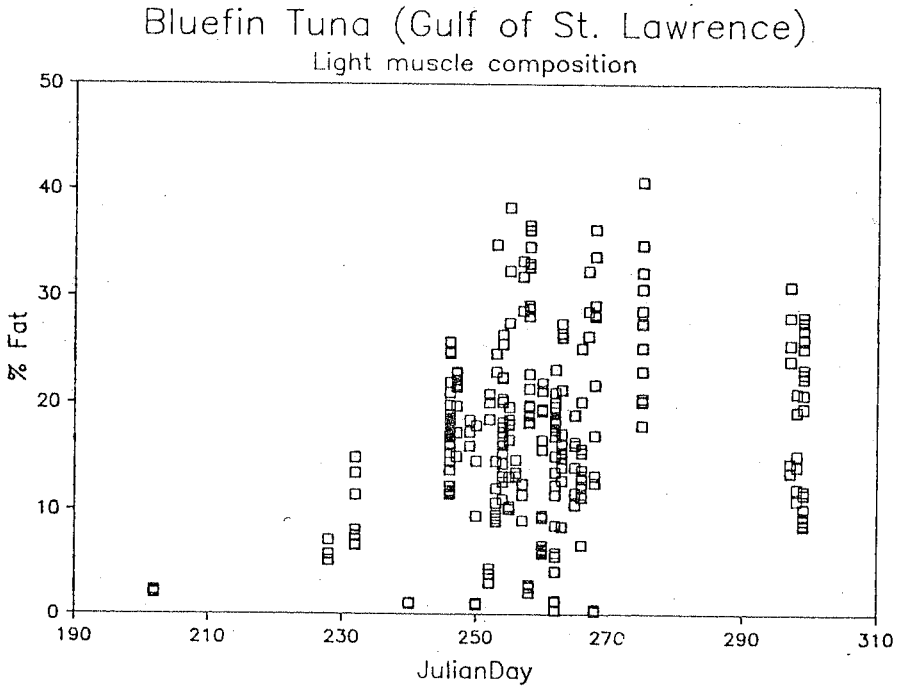

Figure 4. The weak relationship between condition factor calculated from length and weight of Atlantic bluefin tuna and julian day of sampling.

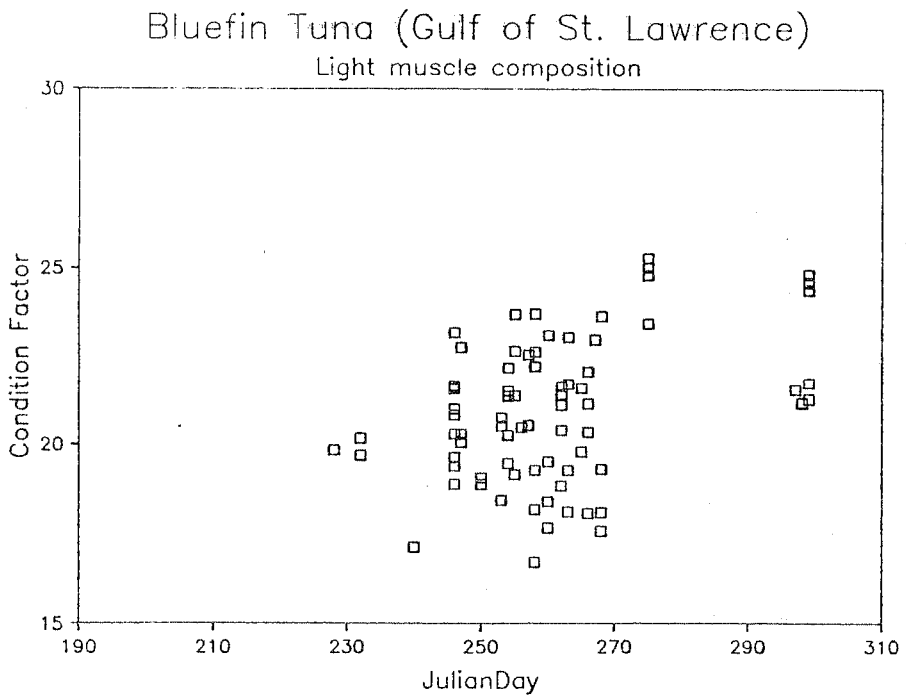

Figure 5. The relationship of % fat versus the sum of the % fat and the % water as measured from the light coloured flesh of Atlantic bluefin tuna.

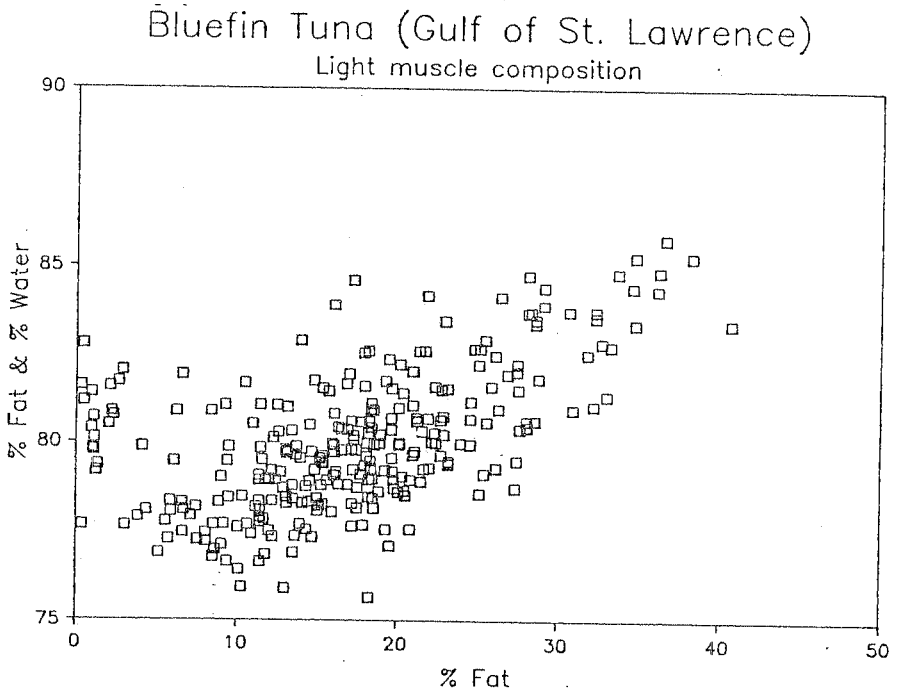

Figure 6. 'Protein-water' relationship of light coloured muscle of Atlantic bluefin tuna.

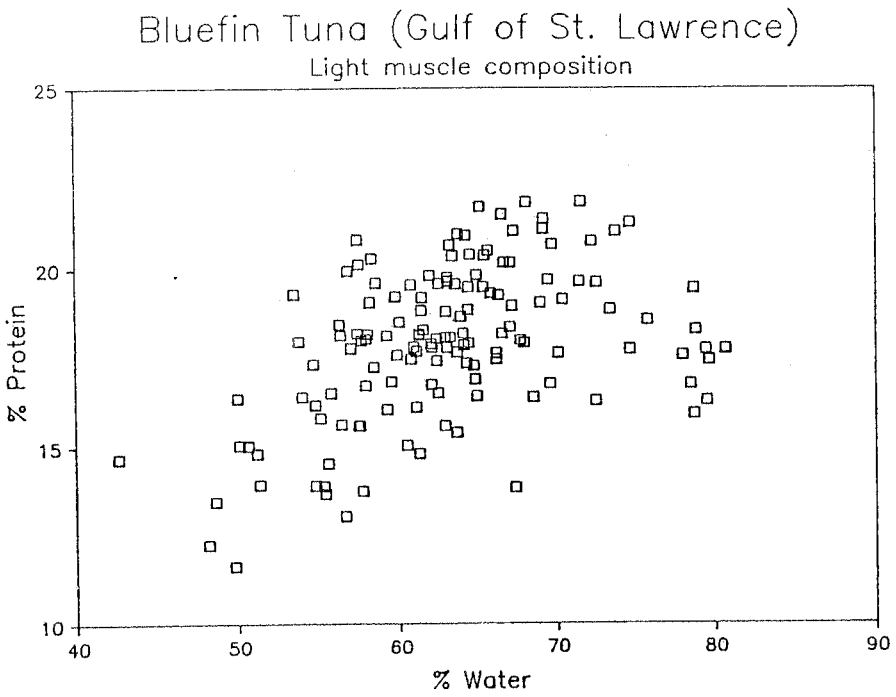

Figure 7. 'Ash-water' relationship of light coloured muscle of Atlantic bluefin tuna.