Fisk. Dir. Skr., Ser. Ernæring, Vol. III, No 2, 3-11 (1990)

A COMPARISON OF THE COMPOSITION OF CULTURED AND WILD CAUGHT EUROPEAN EEL *(ANGUILLA ANGUILLA)*, PARTICULARLY REGARDING LIPIDS

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ABSTRACT

Fillet, liver and visceral fat depots from wild caught eels (mean weight 101 g and 335 g) and farmed eel (mean weight 482 g) were analysed for gross composition and the lipids for fatty acid composition. Lipid contents and dry matter in fillet increased with size and feeding, whereas no differences were found in protein and glycogen contents. The liver glycogen content increased up to about 5% of the liver weight with size and feeding, indicating that eel stores the glycogen mainly in the liver. A higher level of 18:1w9 in fillet and liver in the larger eel compared to the smaller suggests an active *de novo* synthesis. The levels of 18:2w6 and 20:1w9 in fillet and visceral fat depots of farmed eel showed the influence of the diet. The fatty acid composition of the liver lipids points to some transformation of dietary 18:2w6 to 20:4w6 through desaturation and elongation and a preferred energy utilization of the dietary 22:1w11.

INTRODUCTION

The production of farmed eel in Europe in 1989 was approximately 6700 tons, of which about 500 tons were produced in Norway. The nutrient composition of wild caught and reared eel is an important factor of product quality. Eels store lipids in muscle tissue, visceral fat depots and in the liver (Otwell and Rickards, 1981/1982). A high lipid content in eel fillet is a favorable marketable quality influencing wholesale price and consumers acceptance (Otwell and Rickards, 1981/1982). Sea foods are a major source of w3 fatty acids, and the present knowledge about the health effects of these fatty acids, as well as other nutritionally valuable aspects of sea foods, warrant an increased consumption.

The minimum market size for eels in Europe is about 150 g, and the effect of

size on body composition (lipid, protein and dry matter) of eel species has been focussed in several studies (Dave et al., 1974; Gallagher et al., 1984). The objective of this study was to examine the influence of feeding and size on the composition of liver, visceral fat depots and muscle tissue in the European eel, particularly regarding lipids.

MATERIALS AND METHODS

Fish and diets

The fish used in this experiment were two sizes of wild caught eels from the North Sea; average weights (SD) 100.5 g (16.5) and 334.6 g (84.5) and market size eel (Farsund Aqua, Farsund, Norway), average weight 482.3 (13.7). Five fish from each group were analysed. From capture up to market size the eels had been fed each day dry pellets and moist pellets in alternating periods. The two feeds were based on fish-meal, capelin oil and wheat. Gross composition and lipid fatty acid composition of the diets are given in Table 1.

Chemical analyses

Samples of liver, visceral fat depots and fillet were analysed for dry matter, protein, ash, glycogen, total fat and fatty acids. Dry matter was determined gravimetrically after freeze drying. Protein (Nx6.25) was analysed according to Crooke and Simpson (1971). Total fat was measured gravimetrically using ethyl acetate extraction. Ash content was determined as decribed by Mortensen and Wallin (1989). The lipids from liver, visceral fat depots and muscle lipids were extracted with chloroform/methanol (3:1, v/v) and analysed for fatty acid composition as described by Lie et al. (1986). Starch in the feed and glycogen in muscle and fillet were analysed using an enzymatic method as described by Hemre et al. (1989).

Statistics

Oneway analysis of variance (ANOVA) was used for statistical evaluation of the results.

RESULTS AND DISCUSSION

The average weight of small wild caught eel was about 100 g (group 1). This is the size of eel at the start of cultivating in Farsund Aqua. The average weight of large wild caught eel, about 335 g, is the normal market size of wild caught eel from the North Sea. Average weight of market size fed eel was 482 g. The nutrient composition of the three weight groups may be related to size and/or feeding.

Table 1 shows the composition of the two diets. The protein contents were similar in the two diets (45% - 47% on a dry weight basis; 50% of the energy content). According to de la Higuera et al. (1989) minimum protein requirement for optimal growth in eel is 45% of the total energy. The dry matter of the natural diet of wild eels is mainly protein (Lecomte-Finiger, 1983). The lipid contents of the two diets were 21% and 26% on a dry weight basis. Both diets were based on fishmeal and capelin oil; thus there were no major differences in fatty acid composition. The carbohydrate content was low and equal in both diets.

Table 1. Analyses of dry (A) and moist pellets (B); gross composition, starch content and fatty acid composition.

	A	B
Dry matter, %	94.7	49.7
Protein, %	42.5	23.5
Ash, %	7.3	3.6
Starch, %	6.8	2.2
Lipid, %	20.1	12.9
Fatty acid composition (% of total lipid):		
14:0	4.8	6.5
16:0	17.3	20.0
18:0	3.5	3.1
Σ saturated	26.9	30.9
16:1*w*9	5.1 6.7	
16:1*w*7	0.2	0.3
18:1*w*9	11.0	14.7
18:1*w*7	2.0	2.4
20:1*w*9	5.1	4.0
20:1*w*11	0.4	0.4
22:1*w*11	8.8	7.7
Σ monoenes	34.2	38.1
18:2*w*6	7.6	5.2
18:3*w*3	2.2	1.8
18:4*w*3	3.8	2.9
20:4*w*6	0.3	0.3
20:5*w*3	9.2	7.1
22:5*w*3	0.7	0.5
22:6*w*3	11.6	9.6
Σ polyenes	36.3	28.3
*w*3	28.1	22.5
*w*3/*w*6	3.4	3.9

Table 2. Fillet analyses of small wild caught (group 1),large market size wild caught (group 2) and fed market size (group 3) eel.

	Group 1	Group 2	Group 3
Dry matter, %	32.9[a]	40.8[b]	45.3[c]
S.E.M.*	3.9	2.9	1.8
Protein, %	16.8	15.9	14.0
S.E.M.	1.0	0.7	0.7
Lipid, %	12.4[e]	21.7[f]	28.0[g]
S.E.M.	4.7	3.9	2.5
Glycogen, %	0.2	0.1	0.2
S.E.M.	0.0**	0.0	0.0
Ash, %	1.0	0.9	0.8
S.E.M.	0.0	0.0	0.0

* S.E.M. = Standard Error Mean
**S.E.M. values of 0.0 range between 0.00 and 0.05.
Values with the same superscript are not significantly different using ANOVA test, $0.001<p<0.050$.

Table 2 shows the gross composition of fillet from the three samples. Only small differences were seen in protein, ash and glycogen contents, whereas the lipid content was 75% higher in the large wild caught eel compared to the small one. A similar effect of size on composition was reported for the American eel by Gallagher et al. (1984) and Otwell and Rickards (1981/1982). Farmed eel had an even higher lipid content of 28% which may be due to combined effects of size and feeding. Compared with other studies (Otwell and Rickards, 1981/1982) large wild caught eel in this study had a very high lipid content in the fillet, probably an indication of good availability of natural prey. High fat content in eel fillet is a favorable market quality which influences wholesale price and consumers acceptance.

The glycogen values in the eel fillets were low and equalled those in cod (Hemre et al., 1990).

Details of the fatty acid composition of the fillet lipids are given in Table 3. The contents of saturated fatty acids were quite similar in the three samples. The main saturated fatty acid was 16:0 as also reported for the American eel *(Anguilla rostrata)* and for the European eel (Gallagher et al., 1984; Otwell and Rickards, 1981/1982; Degani, 1986). The highest levels of monoenoic fatty acids were observed in the large wild caught eel, with 18:1w9 as the main fatty acid, but with a notable level of 18:1w7 (6.3%). Similar results were reported in the American eel (Otwell and Rickards, 1981/1982). The high lipid content together with a high level of 18:1w9 in the fillet of the larger eel suggest

Table 3. Fatty acid composition of fillet. A comparison between small wild caught (group 1), large market size wild caught (group 2) and market size aquacultured eel (group 3).

	Group 1	Group 2	Group 3
14:0	4.1 (0.3)*	4.6 (0.4)	5.1 (0.2)
16:0	17.3[a] (0.6)	19.0[b] (0.5)	19.2[b] (0.2)
18:0	7.5 (0.7)	9.2 (1.1)	7.0 (0.7)
Σ saturated	26.8 (0.7)	27.6 (1.0)	28.4 (0.5)
16:1*w*9	4.1 (0.3)	3.5 (0.2)	3.6 (0.2)
18:1*w*9	27.2 (3.1)	30.2 (1.3)	24.1 (2.1)
18:1*w*7	4.8[c] (0.3)	6.3[d] (0.7)	2.7[e] (0.2)
20:1*w*9	1.1[f] (0.3)	1.3[f] (0.1)	5.3[g] (0.5)
20:1*w*11	1.0[h] (0.2)	1.0[h] (0.2)	1.8[i] (0.2)
22:1*w*11	nd**	nd	3.7 (1.2)
Σ monoenes	43.7 (2.2)	50.0 (1.6)	45.9 (12.8)
18:2*w*6	1.6[j] (0.1)	0.8[k] (0.1)	3.7[l] (0.3)
18:3*w*3	0.8 (0.5)	0.5 (0.1)	0.9 (0.1)
18:4*w*3	0.2[m] (0.1)	0.1[m] (0.1)	0.8[n] (0.1)
20:4*w*6	1.8[o] (0.3)	1.5[o] (0.2)	0.7[p] (0.2)
20:5*w*3	4.6 (0.3)	4.2 (0.4)	4.5 (0.6)
22:5*w*3	3.5[q] (0.3)	3.1[q] (0.4)	1.9[r] (0.2)
22:6*w*3	8.8 (2.1)	4.8 (1.1)	8.5 (1.2)
Σ polyenes	23.5 (2.3)	16.7 (1.9)	22.7 (2.0)
*w*3	18.9 (2.3)	13.5 (1.7)	17.1 (1.8)
*w*3/*w*6	4.3 (0.3)	4.1 (0.2)	3.4 (0.2)

* The number indicates S.E.M. = Standard Error Mean values
** nd = not detected
Values with the same superscript are not significantly different using ANOVA test, $0.001<p<0.050$.

an active *de novo* synthesis of lipids in this species. The level of 20- and 22-monoenes (representing 11%) in the lipids from fillet of the farmed eel demonstrates the influence of the dietary fatty acids from the capelin oil. A somewhat low level of polyunsaturated fatty acids in the large eel reflects the high content of triglycerides in the fillet with a lower content of polyunsaturated fatty acids (PUFA) than the phospholipids. Otwell and Rickards (1981/1982) reported similar results in American eel. The main polyenes were 22:6*w*3 and 20:5*w*3, but also noteworthy high levels of 22:5*w*3 were found. In farmed eels the content of of 3.7% of 18:2*w*6 showed the influence from the feed, as also demonstrated in glass eel by Degani (1986). Nevertheless, the level of 20:4*w*6 was lower in the farmed eel than in the wild caught eel.

The relative high content of 22:6*w*3 (8.5%) and the high lipid content (28%) suggest the possibility of increasing the *w*3 level in the muscle by manipulation

Table 4. Liver analyses of small wild caught (group 1), large market size wild caught (group 2) and fed market size (group 3) eel.

	Group 1	Group 2	Group 3
Dry matter, %	29.5	32.2	28.0
S.E.M.*	1.6	1.0	0.5
Protein, %	14.2	13.3	14.0
S.E.M.	0.6	0.3	0.5
Lipid, %	9.0 [a]	10.9 [a]	3.8 [b]
S.E.M.	1.3	0.2	0.8
Glycogen, %	1.7 [c]	3.3 [d]	5.5 [e]
S.E.M.	0.5	1.3	0.3
Ash, %	0.9	1.0	1.0
S.E.M.	0.1	0.0**	0.0

* S.E.M. = Standard Error Mean
**S.E.M. values of 0.0 range between 0.00 and 0.05.
Values with the same superscript are not significantly different using ANOVA test, $0.001<p<0.050$.

of the fatty acid composition in the feed. In view of the present interest in the value of $\omega 3$ fatty acids in human nutrition, these results point to the importance of the feed fat composition for the product quality of farmed eel.

The hepatosomatic index was small, representing 1 and 3% of total body weight. Table 3 shows the gross composition of the liver samples. No difference was seen in dry matter or in the amount of protein and ash. The liver glycogen contents significantly increased from group 1 to group 3. The difference between wild caught small and large eel shows a size effect, while the relative large increase in liver glycogen between group 2 and 3, in spite of a smaller weight difference indicates a combined effect of size and nutrition. Evidently the eel stores its glycogen reserves mainly in the liver. This has also been reported for other carnivorous fish species e.g. in cod (Hemre et al., 1990). There was a significantly lower content of total fat in farmed eel liver, while no difference were found between small and large wild caught eel.

Equal contents of saturated fatty acids in liver were seen in the two wild caught eel groups, and as for the fillet palmitic acid was the main fatty acid (Table 5). The level of monoenoic fatty acids, primarily 18:1$\omega 9$, was higher in the large wild caught eel than in the smaller one, balanced with a reduction in the PUFA. The liver lipid of farmed eel had increased levels of saturated fatty acids, mainly 16:0 and 18:0, whereas the monoenoic and PUFA levels were similar to those in the small wild caught eel.

Table 5. Fatty acid composition of liver. A comparison between small wild caught (group 1), large market, size wild caught (group 2) and market size aquacultured eel (group 3).

	Group 1	Group 2	Group 3
14:0	2.7 (0.4)*	3.2 (0.3)	2.3 (0.2)
16:0	16.3 [a] (0.9)	15.0 [a] (0.8)	19.3 [b] (1.1)
18:0	3.7 [c] (0.3)	3.4 [c] (0.3)	8.9 [d] (0.4)
Σ saturated	23.9 [e] (1.2)	22.4 [e] (1.3)	31.3 [f] (1.6)
16:1*w*9	7.3 [g] (0.3)	8.6 [g] (0.3)	2.1 [h] (0.1)
18:1*w*9	25.3 [i] (3.5)	36.6 [j] (2.4)	25.5 [i] (3.0)
18:1*w*7	5.5 [k] (0.5)	5.7 [k] (0.7)	0.6 [l] (0.1)
20:1*w*9	1.2 [m] (0.1)	1.3 [m] (0.3)	2.6 [n] (0.1)
20:1*w*11	0.6 [o] (0.2)	0.4 [o] (0.1)	2.9 [p] (0.1)
22:1*w*11	nd**	nd	1.4 (0.4)
Σ monoenes	41.9 (2.4)	54.1 (3.0)	37.2 (3.2)
18:2*w*6	1.3 [q] (0.1)	0.6 [r] (0.1)	1.4 [q] (0.2)
18:3*w*3	0.6 [s] (0.1)	0.3 [t] (0.1)	0.2 [t] (0.0***)
18:4*w*3	nd	nd	0.2 (0.1)
20:4*w*6	2.9 (0.3)	2.5 (0.4)	3.2 (0.5)
20:5*w*3	4.5 [u] (0.4)	2.6 [v] (0.4)	6.0 [u] (1.0)
22:5*w*3	4.1 [w] (0.4)	3.3 [w] (0.5)	1.6 [x] (0.3)
22:6*w*3	13.5 [y] (2.1)	6.8 [z] (0.5)	15.8 [y] (2.1)
Σ polyenes	28.8 [æ] (2.1)	17.4 [ø] (1.4)	31.5 [æ] (3.0)
*w*3	23.7 [a] (2.1)	13.6 [b] (1.0)	24.0 [a] (3.2)
*w*3/*w*6	4.7 (0.4)	3.6 (0.3)	4.8 (0.4)

* The number indicates S.E.M. = Standard Error Mean values
** nd = not detected
*** S.E.M. values of 0.0 range between 0.00 and 0.05.
Values with the same superscript are not significantly different using ANOVA test, $0.001<p<0.050$.

Table 6 details the fatty acid composition of the visceral lipids. No statistical significant differences were found between small and large wild caught eels. The fatty acid composition was quite similar to that found in fillet lipids, both in wild caught and farmed eels, and reflects that these two tissues are the main lipid storages in the eel.

The dietary influence of linoleic acid, 18:2*w*6, from the diet of farmed eel was seen both in fillet and visceral fat depots, whereas a lower level of 20:4*w*6

Table 6. Fatty acid composition in visceral fat depots. A comparison between small wild caught (group 1), large market size wild caught (group 2) and market sized aquacultured eel (group 3).

	Group 1	Group 2	Group 3
14:0	4.1 [a] (0.3)*	4.5 [a] (0.3)	5.3 [b] (0.3)
16:0	17.1 (0.7)	18.7 (0.4)	18.6 (0.4)
18:0	4.7 [d] (0.4)	3.5 [e] (0.2)	4.1 [d] (0.1)
Σ saturated	26.7 (0.6)	27.9 (1.0)	28.7 (0.8)
16:1*w*9	7.2 (0.9)	9.5 (0.6)	6.4 (0.8)
18:1*w*9	31.3 (2.9)	32.0 (1.8)	24.6 (2.5)
18:1*w*7	3.4 (0.9)	3.7 (0.5)	2.7 (0.2)
20:1*w*9	1.5 [j] (0.5)	1.5 [j]	
20:1*w*11	1.1 (0.4)	1.2 (0.4)	2.0 (0.2)
22:1*w*11	nd**	nd	3.8 (0.7)
Σ monoenes	46.6 (1.5)	49.5 (1.5)	46.9 (2.6)
18:2*w*6	1.8 [a] (0.1)	1.1 [a] (0.2)	4.3 [b] (0.4)
18:3*w*3	0.7 (0.2)	0.5 (0.1)	0.9 (0.1)
18:4*w*3	0.2 [r] (0.1)	0.2 [r] (0.2)	0.8 [s] (0.1)
20:4*w*6	2.3 [t] (0.6)	1.6 [t] (0.5)	0.5 [u] (0.0***)
20:5*w*3	4.2 (0.4)	4.2 (0.2)	4.0 (0.3)
22:5*w*3	3.6 [w] (0.3)	3.2 [w] (0.3)	1.8 [x] (0.1)
22:6*w*3	7.7 [y] (1.8)	4.8 [y] (1.4)	8.0 [z] (0.7)
Σ polyenes	22.6 (2.3)	17.0 (1.6)	22.4 (1.8)
*w*3	17.5 (2.2)	13.4 (1.6)	16.2 (1.3)
*w*3/*w*6	3.6 (0.2)	3.6 (0.2)	3.0 (0.2)

* S.E.M. = Standard Error Mean
** nd = not detected
***S.E.M. values of 0.0 range between 0.00 and 0.05.
Values with the same superscript are not significantly different using ANOVA test, $0.001<p<0.050$.

was seen in both tissues compared to the values in the wild caught eels. However, equal level of 18:2*w*6 as well as 20:4*w*6 were found in liver lipids of wild caught small and farmed eels. Together with 3.2% of 20:4*w*6 minor contents of 20:2*w*6 (0.3%) and 20:3*w*6 (0.4%) were found in the liver lipids of farmed eel, suggesting that the eel has some ability to elongate and desaturate dietary 18:2*w*6 to 20:4*w*6.

The feed lipids contained substantial amounts (8-9%) of 22:1*w*11, whereas the level in both fillet and visceral lipids of farmed eels was below 4% (1.4-3.8%). Oleic acid, 18:1*w*9, was the main monoenic fatty acid in all tissues (approx. 25%), compared to the feed lipid contents of 11-15%. These results point to a preferred utilization of 22:1*w*11 as an energy source in eel as also

reported for other fish species (Sargent et al., 1979; Lie et al., 1986; Lie and Lambertsen, 1990). The tissue levels of 20:1w11, 2-3% relative to 0.4% in the feed, suggest that peroxisomal chain shortening of 22:1w11 to 20:1w11 is a possibility, while 18:1w11 was not detected in any of the tissue lipids. Whereas the 20:5w3/22:6w3ratio of the feeds was 0.8, the ratio was 0.5 in the tissues analysed, suggesting a chain elongation of 20:5w3 to 22:6w3

REFERENCES

CROOKE, W.M. and SIMPSON, W.E. 1971. Determination of ammonium in Kjeldal digests of crops by an automated procedure. J. Sci. Fd. Agric., *22*, 9-10.

DAVE, G., JOHANSSON M.L., LARSSON, A., LEWANDER, K. and LIDMAN, U. 1974. Metabolic and hematological studies on the yellow and silver phases of the European eel, *Anguilla anguilla* L.-II. Fatty acid composition. Comp. Biochem. Physiol. *53B*, 509-515.

DEGANI, G. 1986. Dietary effects of lipid source, lipid level and temperature on growth of glass eel *(Anguilla anguilla)*. Aquaculture, *56*, 207-214.

de la HIGUERA, M., GARCIA GALLEGO, M. SANZ, lA., HIDALGO, M.C. and SUAREZ, M.D. 1989. Utilization of dietary protein by the eel *(Anguilla anguilla)*. Optimum dietary protein levels. Aquaculture, *79*, 53-61.

GALLAGHER, M.L., KANE, E. and BERINGER, R. 1984. Effect of size on composition of the american eel, *Anguilla rostrata*. Comp. Biochem. Physiol., *78A*, 533-536.

HEMRE, G.I., LIE, Ø., LIED, E. and LAMBERTSEN, G. 1989. Starch as and energy source in feed for cod *(Gadus morhua)*: Digestibility and retention. Aquaculture, *80*, 261-270.

HEMRE, G.I., LIE, Ø., LAMBERTSEN, G. and SUNDBY, A. 1990: Dietary carbohydrate utilization in cod *(Gadus morhua)*. Hormonal response of insulin, glucagon and glucagon-like peptide to diet and starvation. Comp. Biochem. Physio., *97A*, 41-44.

LECOMTE-FINIGER, R., 1983. Régime alimentaire des civelles et anguillettes *(Anguilla anguilla)* dans trois étanges saumaters du roussillon. Bull. Ecol., *14*, 297-306.

LIE, Ø., LIED, E. and LAMBERTSEN, G. 1986. Liver retention of fat and fatty acids in cod *(Gadus morhua)* fed different oils. Aquaculture, *59*, 187-196.

LIE, Ø. and LAMBERTSEN, G. 1990. Lipid digestion and absorption in cod *(Gadus morhua)*, comparing triacylglycerols, wax esters and diacylalkylglycerols. Comp. Biochem. Physiol., in press.

MORTENSEN, A.B. and WALLIN, H. 1989. Food composition: Gravimetric determination of ash in foods: MNKL collaborative study. J. Assoc. Off. Anal. Chem. *72*, 481-483.

OTWELL, W.S. and RICKARDS, W. 1981/1982. Cultured and wild American eels, *(Anguilla rostrata)*: fat content and fatty acid composition. Aquaculture, *26*, 67-76.

SARGENT, J.R., MCINTOSH, R., BAUERMEISTER, A. and BLAXTER, J.H.S. 1979. Assimilation of the wax esters in marine zooplankton by herring *(Clupea harengus)* and rainow trout *(Salmo gairdneri)*. Marine Biology. *51*, 203-207.