International Council for the Exploration of the sea

C.M. 1984/F:25
Mariculture Committee

CAUSES OF VARIATION IN CARCASS TRAITS OF ATLANTIC SALMON (Salmo salar).

by

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ABSTRACT

The aim of the present study was to reveal causes of variation in carcass traits of farmed Atlantic salmon (Salmo salar).

During slaughtering of one year class Atlantic salmon, composed of half sib and full sib groups, samples for determination of carotenoid levels in flesh and ovaries were collected. Also the hepatosomatic and viscerosomatic indexes as well as relative visceral fat content were determined.

As expected it was found that these traits were influenced by several factors. The material is too limited for firm conclusions, but evidently the carotenoid level depends largely on stage of maturity and possibly also on genetic factors. Genetic factors seem to influence the visceral fat content. In hepatosomatic and visceral indexes, and possibly in visceral fat content, a strange and still unexplained interaction between sex and stage of maturation was observed.

INTRODUCTION

Compared to most domesticated species, the artificial propagation of Atlantic salmon (Salmo salar) is new, and in commercial fishfarming, practiced only a couple of decades. Therefore only a few generations have been exposed to selection for economic importante traits in fish farming.

Gjedrem (1983) ranked the relative importance of some traits as; growth rate (+++), meat quality (++), late mortality (++), age at sexual maturation (++), early mortality (+) and fecundity (0).

Even though there might be some discussion about this ranking,

and also the definition of some of these traits, the selection goals of Atlantic salmon and also rainbow trout (Salmo gairdneri) have so far focused on growth rate (Nævdal et al, 1978 and 1979, Gunnes and Gjedrem, 1978, Gjerde and Gjedrem, 1984) and also age at sexual maturation (Nævdal, 1983).

Selection for meat quality, mortality rates or feed conversion have not been made. However, Gjerde and Gjedrem (1984) studied genetic and phenotypic correlations for; 1: gutted and ungutted body weight, 2: body length, 3: dressing persentage, 4: meatiness, 5: meat colour, 6: liver colour and 7: maturity. The traits 3 to 6 was determined by subjective score. Moreover, Torrissen and Nævdal (1984) found differences in the level of carotenoids in the flesh between full sib-groups and paternal half sib-groups of rainbow trout.

In the present study effecting factors such as; genetic, sex, sexual maturation, age at smoltification and fish size, on flesh and ovarian carotenoid level, on hepatosomatic and viscerosomatic indexes of 4-4.5 year old Atlantic salmon were investigated.

MATERIAL AND METHODS

The experiment was based on family groups of Atlantic salmon (Salmo salar) from the breeding program at the Institute of Marine Research, Bergen, Norway.

Eggs and milt were collected from the broodstock at two commercial fish farms in the autumn of 1978. The eggs were fertilized, waterhardened and transported to Matre Aquaculture Station, Matredal, where they hatched during the spring 1979 and were reared to the smolt stage.

The fish smoltified in spring 1980 were marked by fin clipping and freeze branding and thereafter transferred to floating cages in brackish water.

During the summer the non smoltified fish were sorted and fish reaching a size of 10 to 12 cm marked and transfered to the floating cages during the autumn. All fish were transported to Austevoll Aquaculture Station, Storebo in may 1981. The two smolt groups are refered to as 1- and 2- year smolts.

At Matre Aquaculture Station the fish were fed a commercial dry pellet diet and at Austevoll Aquaculture Station a moist pelleted diet made mainly of fish meal, capelin, krill, fish oil, and commercial binder mixture containing vitamins.

In June 1983 both smolt age-classes were starved for about one week and slaughtered. Sex, sexual maturation, total length and weight to nearest 100 g were recorded. The viscera, liver and gonads were weighed to nearest 1 g and collected for fat determination. Muscle and ovary samples of about 1 g were collected and analysed for carotenoids as described by Torrissen and Nævdal (1984). The carotenoids were identified by thin layer chromatography (Lambertsen and Braekkan, 1971). The dry matter was determined by drying at 105°C to constant weight and fat content by diethyl ether extraction.

Hepatosomatic index was calculated as liver weight (g)/ fish weight (kg) and viscerosomatic index as weight of viscera (g)/ fish weight (kg).

Statistical analysis was carried out by using the BMDP statistical software, P2V and P4V, (Dixon, 1981) and RS/1 (Bolt Beranek and Newman, Inc., Cambridge, Massachusetts, USA)

RESULTS.

Carotenoid level in the flesh.

Astaxanthin and cantaxanthin were found to be the major carotenoids in the flesh.

The carotenoid level was determined in the flesh of 686 fishes, whereof 532 transferred to sea as 2 year old smolt and 154 as 1 year old. The average level of carotenoid in the flesh were 4.61 mg/kg. The results are sumarized in Fig. 1.

The mean level of carotenoids in the full sib-groups ranged from 3.67 mg/kg to 5.57 mg/kg, a range of 42% of the total mean value. The difference among the groups were not significant, p=0.18. However, when eliminating the effect of sex, a significant effect of full sib groups was indicated.

The level of carotenoids in the groups of 1- and 2- years smolts were significantly different (p=0.0000). The stage of sexual maturation also influenced significantly the carotenoids in the flesh (p= 0.0000). The level was highest in immature, somewhat lower in the fish maturing for first time, and lowest in reconditioning spawners. Between the sexes significant differences were found (p=0.016). These differences were, however, not significant when the effect of maturation was eliminated (p=0.36). Also differences connected with fish weight were significant (P=0. 023). The highest mean content was found in medium sized groups.

The results are summarized in Fig. 1.

Carotenoids in ovaries

The carotenoid level was determined in the ovaries of 159 females. The mean level was 18.? mg/kg. There was no significant difference in ovarian carotenoid level neither between immature and maturing fish (p=0.09) nor between different weight groups (p=0.53). The materials were too limited to be analyzed according to differences between sib groups.

Hepatosomatic index

The average hepatosomatic index was found to be 10.6g/kg (406 fish). No significant difference was found between the full sib-groups (p=0.58), but the hepatosomatic index decreased by increasing fish weight (p=0.0000). Neither the difference between the sexes nor between immature and maturing fish were significant, p=0.38 and 0.16 respectively, but the interaction between sex and maturation was statistically significant (p=0. 0010), see Fig. 2.

Viscerosomatic index and visceral fat deposition.

The viscerosomatic index was measured in 382 fish and the average level was 60.5 g/kg. The difference between sexes and between immature and maturing fish were not significant; p=0. 15 and 0.81 respectively. However, the interaction between sex and stage of maturation was significant (p=0.0007) , Fig. 2. The difference between full sib-groups was significant (p= 0.0094) and also the covariance between fish weight and the viscerosomatic index (p=0.0000).

The average visceral fat deposition was measured to 12.5g/kg fish. The difference between the full sib-groups was significant, p=0.0152, but no significant covariation between fish weight and visceral fat deposition was found. Neither the difference between the sexes nor stage of maturation was significant. Also in this trait an interaction between sex

and stage of maturation was observed (Fig. 2) although it was not statistically significant (p=0.18), Fig. 2.

The relation between the hepatosomatic index and sexual maturation and the relative visceral fat is shown in Fig. 3. The level of visceral fat was significantly different between the fish grouped by the hepatosomatic index (p=0.0000) when including sexual maturation (p=0.0645) in the statistical analysis. The interaction between hepatosomatic index and sexual maturation was also significant (p=0.0000).

DISCUSSION

Pigmentation.

Carotenoid pigments are absorbed from the diet and deposited as such, mainly in flesh, ovaries and skin. The red carotenoids, astaxanthin and also cantaxanthin, are added to the diet of commercial reared Atlantic salmon to obtain the "Salmon colour" of the flesh.

However, the flesh colour is also influenced by other factors. Fat layers and intramuscular fat might cover the red flesh colour. Feeding salmon with high level of vegetable feed ingredients might also distort the colour by astaxanthin or cantaxanthin by introducing other carotenoids or other coloured substances in the flesh.

Gjedrem (1976), Refstie and Austreng (1981) and Gjerde and Gjedrem (1984) determined the flesh colour visually in family groups of Atlantic salmon and rainbow trout. Subjective score is strongly influenced by the factors mentioned above. The relation between carotenoid level in flesh and visual score is also more likely to be logaritmic than linear, giving low sensitivity at high levels of carotenoids in the flesh.

Also the method used for determination of carotenoid level in this experiment (Torrissen and Nævdal, 1984) have limitations. The fat in flesh dissolves in the extract and increase a volumetric error. However, the error is small as an 1% increase in fat level in flesh result in about 0.2% relative underestimation of carotenoids.

Variation in flesh pigmentation (carotenoid level) is caused by several factors. In this study the stage of maturation, sex and fish size are found to influence this trait, and when eliminating variations caused by these, also variations caused by genetic factors are indicated. The present materials, however, are too limited for thorough analysis of causes of variation in flesh pigmentation of Atlantic salmon. The probable genetic variation, however, are less clear than the one found in rainbow trout (Torrissen and Nævdal, 1984), This may be due to the inhomogeneity of the material which make the interpretation difficult and thus it also will be difficult to draw firm conclusions.

Gjerde and Gjedrem (1984) concluded that there is a heritable variation in the ability to utilize the available carotenoids in the feed and deposite them in the flesh. The present experiment, and also Torrissen and Nævdal (1984), confirms that there might be genetic variances in the carotenoid level in flesh of salmonids fed the same diet. None of these studies, however, presents data satisfactory enough for concluding a difference in utilization or ability to deposite carotenoids in the flesh.

The present materials are too limited for a thorough analysis of ovarian pigmentation. The level was about the same in the growing ovaries of maturing females as in the immature ovaries of the immatures, and accordingly the total amounts of carotenoids were very different. The level of carotenoids in

the maturing ovaries will probably change greatly later in the season as found by Torrissen and Torrissen (1984).

Hepatosomatic index, viscerosomatic index and relative visceral fat.

High content of visceral fat will cause high viscerosomatic index and thus more waste products. Selection for low content of visceral fat thus will be a genetic improvement. In this trait, sib groups were the only factor which influenced the values significantly, and therefore a genetic component in the ability to deposit visceral fat seem to be present. This indicate that genetic improvement for this trait may be possible.

The variations in the two other dependent variables, hepatosomatic and viscerosomatic indexes, are not easy to interpret. Both showed decreasing values with increasing fish weight, indicating that the relative amount of flesh is higher for larger fish than for smaller ones. The apparent effect of sib-groups on viscerosomatic index, even not significant, probably reflects the indicated genetic variation in visceral fat content.

Both indexes showed an interacting variation between sex and stage of maturity. From Fig. 2, it is evident that immature males have considerable higher mean hepatosomatic and viscerosomatic indexes than maturing males, while the mature females have higher means than the immature ones. The tendency is the same in relative fat content although less evident and not statistically significant, Fig. 2.

Gjerde and Gjedrem (1984) found that the heritability for dressing percentage was not different from zero (Weight of ungutted X 100/Weight of gutted). However, they measured gutted and ungutted weights to the nearest 100 g, getting

considerable error in measurement of fish weighing from 2.67 to 5.71 kg in average. This does not explain the difference between the dressing percentage they found, 88 to90%, and the viscerosomatic index found in the present experiment, 60 g/kg. The dressing percentage, even not stated, probably used an ungutted and washed fish were the kidneys are removed. The viscerosomatic index does not include kidneys and body mucous. This is probably the main difference, even though there might also be some differences in visceral fat content.

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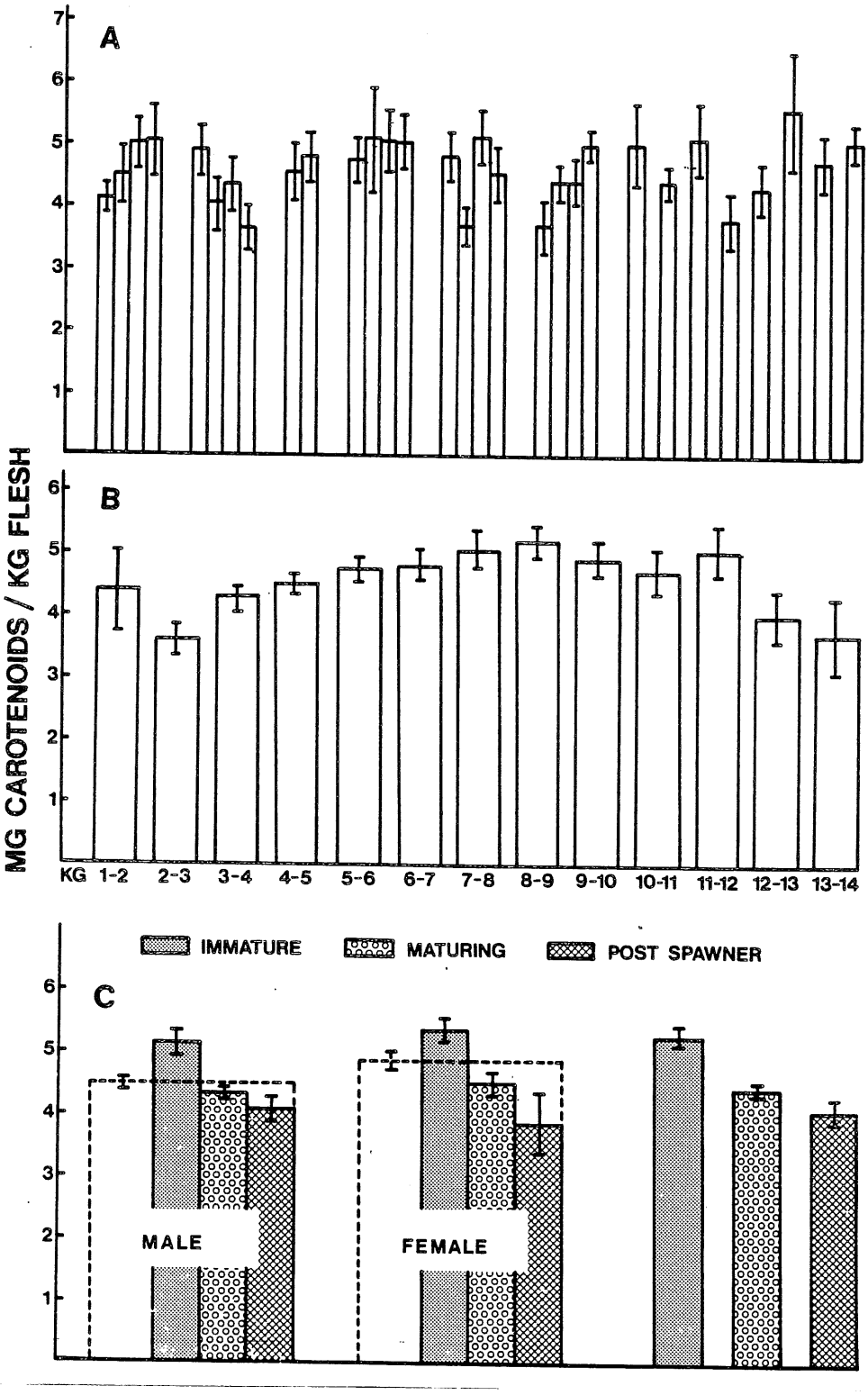

Fig. 1. The carotenoid level in flesh of Atlantic salmon; A: in full sib-groups. Full sib-groups with same father are grouped together. B: in different weight classes.
C: means in male and female grouped by sexual maturity.
The bars give Standard Error of Mean (S.E.M.)

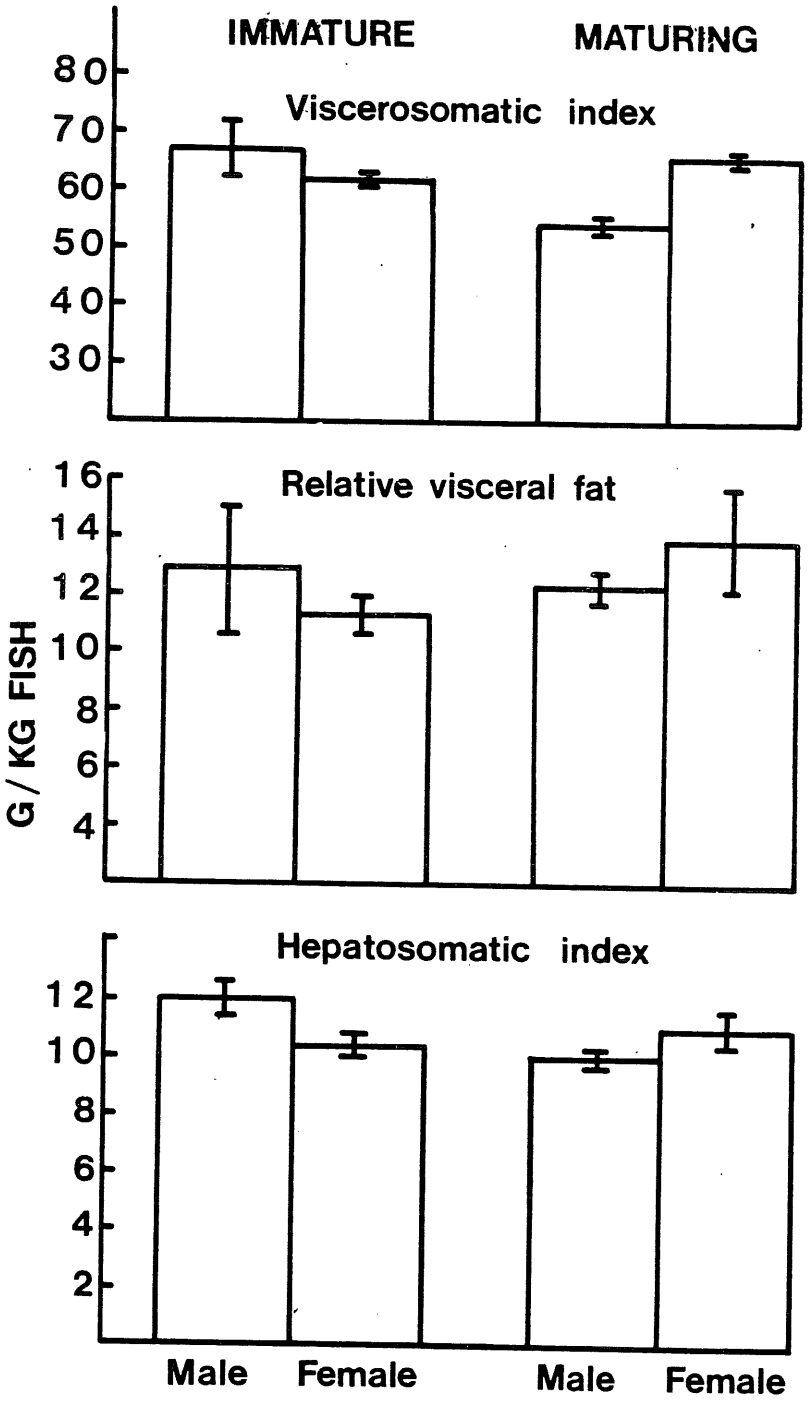

Fig. 2. The Viscerosomatic index, relative visceral fat and hepatosomatic index for immature and maturing male and female Atlantic salmon.
The bars give Standard Error of Mean (S.E.M.).

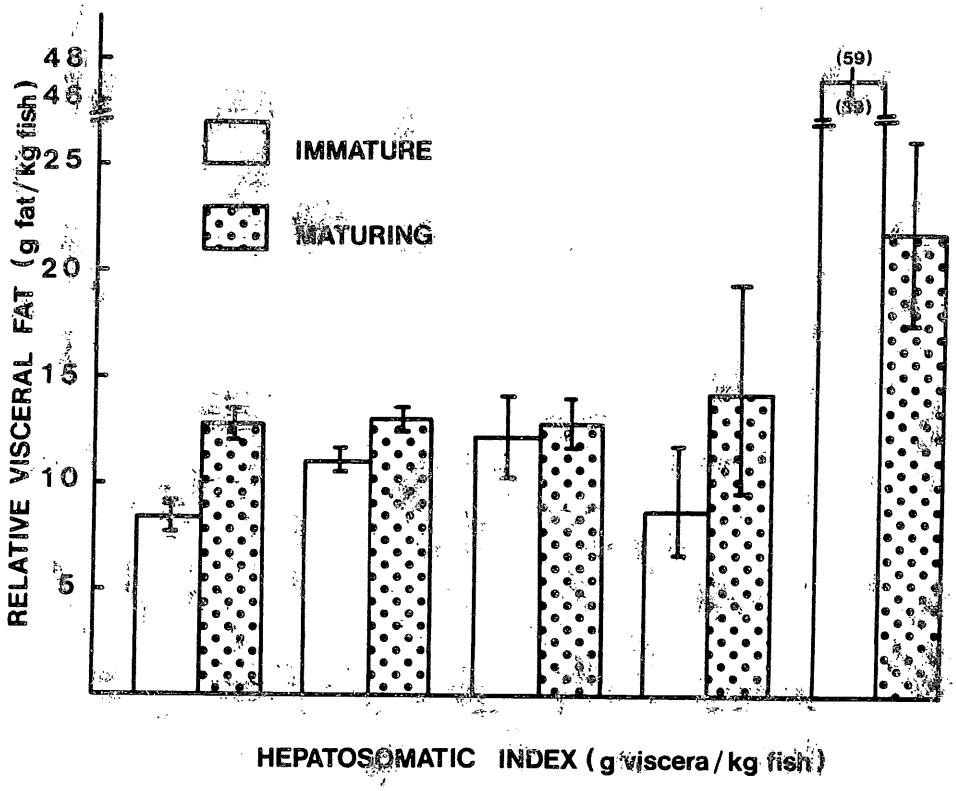

Fig. 3. The relation between hepatosomatic index and the relative visceral fat.
The bars give Standard Error of Mean.