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Lipid characterisation and distribution in the fillet of the farmed Australian native fish, Murray cod (*Maccullochella peelii peelii*)

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Abstract

The objective of this study was to determine the distribution pattern of lipids and fatty acids in different tissues of farmed Murray cod (*Maccullochella peelii peelii*).

Differences in lipid content were found amongst different portions of the fillet, being lowest in the dorsal/cranial portion (P1) and highest in the more ventral/caudal portion (P8) ($P < 0.05$). The latter also recorded the highest amount of monounsaturated fatty acid (MUFA) and the lowest in polyunsaturated fatty acids (PUFA), arachidonic acid, $20{:}4n-6$ (ArA), docosahexaenoic acid, $22{:}6n-3$, (DHA) and the $n3/n6$ ratio. In general, lipid content in the different fillet portions was inversely correlated to PUFA and directly to MUFA. Contents of saturated fatty acids (SFA) and eicosapentaenoic acid, $20{:}5n-3$ (EPA) did not show any discernible trends in the different fillet portions, while significant differences in contents of DHA and ArA were observed. This study shows that lipid deposition in Murray cod varies markedly and that different fatty acids are deposited differently throughout the fillet.
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Keywords: EPA; DHA; Fillet portions; PUFA; Fatty acids

1. Introduction

Fish, in view of their content of long chain polyunsaturated fatty acids (LC-PUFA) are renowned to be highly beneficial to human health (Connor, 2000). Consequently, an increase in consumption of $n-3$ LC PUFA rich foods is universally recommended (Simopoulos, Leaf, & Salem, 1999). In spite of this, there is evidence that the intake of EPA and DHA in developed countries is well below the advisable daily intake (ADI) (Logan, 2004; Ollis, Meyer, & Howe, 1999), which is perhaps related to low fish consumption (Delgado, Wada, Rosegrant, Meijer, & Ahmed, 2003).

Marine and freshwater finfish, crustaceans, and to a lesser extent marine algae, are some of the best natural sources of DHA and EPA (Ackman, 1988; Thomas & Holub, 1994). Therefore, consumers expect to find many of the beneficial $n-3$ fatty acids in fish available on the market, and also in species cultured in intensive aquaculture systems.

It is well known that lipid distribution and fatty acid composition in fish muscle vary greatly depending on the species (Ackman, 1967), diet composition and feeding regimes (Shearer, 2001), husbandry practices and environmental conditions (Pottinger, 2001). Previous studies on salmonids (Bell et al., 1998; Katikou, Hughes, & Robb, 2001; Testi, Bonaldo, Gatta, & Badiani, 2006; Toussaint et al., 2005) and yellowtail (*Seriola quinqueradiata*) (Thakur, Morioka, Itoh, & Obatake, 2002; Thakur, Morioka, Itoh, & Obatake, 2003) have also shown that lipid distribution varies greatly depending on the section and type of muscle.

On the other hand, the organoleptic properties of fish, especially freshwater fish, are in part influenced by flavour volatile compounds derived from the oxidation of unsaturated fatty acids, mainly PUFA (Ackman, Eaton, & Linke,

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1972; Prost, Sérot, & Demaimay, 1998; Sérot, Regost, & Arzel, 2002). In addition, lipids can affect the texture of fish (Dunajski, 1979; Johnston et al., 2000; Thakur, Morioka, & Itoh, 2005). For this reason, the lipidic fraction of fish is extremely important both from a nutritional point of view and from an organoleptic perspective.

Nevertheless, there are no accurate descriptions of lipid deposition patterns in many fish species, in particular in warm water, freshwater carnivorous species. Much research has been done on the carcass, whole fillet and some sections considered representative of the whole fillet (Francis, Turchini, Jones, & De Silva, 2006; De Silva, Gunasekera, & Ingram, 2004; Turchini, Gunasekera, & De Silva, 2003a). However, the possible differences in deposition patterns can have major consequences in nutritional and sensorial analyses as well as consumer acceptability of the product, as the portion under investigation can be significantly different from a portion located on a different area of the same fillet.

Murray cod, *Maccullochella peelii peelii* (Mitchell), is the largest Australian native, warm water, freshwater fish. It is particularly popular amongst Asian consumers as it resembles the Chinese Mandarin fish, *Siniperca chuatsi* (Basilewski), which is considered one of the most valued warm water freshwater species commercially cultured (De Silva et al., 2004). In recent years there has been much interest in Murray cod culture due to its large size, fast growth rates, suitability to high stocking densities and good edible qualities. Currently Murray cod supports a small but a well established and fast growing, aquaculture industry within Australia (Ingram, De Silva, & Gooley, 2005).

The objective of this study was therefore, to characterise the lipid composition of different tissues of commercially farmed Murray cod and to map the lipid and fatty acid deposition patterns in different portions of the fillet. It is expected that the findings will provide useful suggestions to researchers interested in lipid and fatty acid partitioning in Murray cod and to potential Murray cod producers and consumers, and also shed light on procedures for organoleptic testing in fish.

2. Materials and methods

2.1. Fish

For the purpose of this study three sizes of Murray cod (*Maccullochella peelii peelii*) (small, 285 ± 11 g; medium, 692 ± 40 g; large, 1824 ± 179 g) were randomly selected from a stock maintained in the intensive recirculating aquaculture system of a commercial farm, Spirit of the Sea Aquaculture, Warrnambool, Australia. Medium size fish are generally the preferred market size.

Fish were fed two commercial diets (Skretting Nova ME, Tasmania), 9 mm (D9) for small and medium size fish and 11 mm (D11) for large size fish during the months prior to the trial. The two diets were nutritionally similar (Moisture = 8%, Crude protein = 45%, Total lipid = 20%, Ash = 9%, Energy = 21.7 kJ g^{-1}), differing only in pellet size. Fish were culled using ice slurry, bled and stored at −20 °C until needed for analysis.

2.2. Sampling procedure

Twelve fish for the small size class and 6 fish for the medium and large size classes were chosen for this study. The small fish were used in pairs and the resulting homogenate was combined and used for analysis. After defrosting at 4 °C for 18 h the fish were gutted, the perivisceral fat and liver removed, filleted and skinned. The left fillet was divided into nine portions, according to the muscle lines and main anatomical features (Fig. 1) and a code (P1, P2,...,P9) was assigned to each portion: P1 = Dorsal–Cranial, P2 = Dorsal–Central, P3 = Frontal–Lateral, P4 = Central–Lateral, P5 = Belly flap, P6 = Dorsal–Caudal, P7 = Caudal–Central, P8 = Caudal–Ventral and P9 = Caudal, and each portion accounted approximately for 10.5 ± 0.8, 9.8 ± 0.6, 15.8 ± 1.2, 18.3 ± 1.1, 13.5 ± 1.1, 5.2 ± 0.4, 14.0 ± 0.7, 5.4 ± 0.6 and 7.3 ± 0.8% by weight of the fillet, respectively.

The right fillet was used for proximate and fatty acid analyses of the whole fillet. Each portion and the whole fillet were homogenised using a mini food processor (Black and Decker, Sydney Australia). Perivisceral fat and liver were reduced to a homogenous paste by hand using a mortar and pestle.

2.3. Biometric parameters

The main biometric parameters determined included total length (TL), total weight (TW), somatic weight (SW), liver weight (LW), fillet weight (FW), viscera weight (VW) and perivisceral fat (PW). All weights were in g and length in cm.

The following biometric parameters were also estimated:

Condition factor: $K = (TW/L^3) \times 100$;
Hepatosomatic Index: HSI (%) = $(LW/TW) \times 100$;
Dress-out percentage (%) = $(SW/TW) \times 100$;
Fillet yield (%) = $(FW/TW) \times 100$ and
Visceral fat index (%) = $(PF/TW) \times 100$.

2.4. Proximate composition

Proximate composition of diets and muscle was determined according to standard methods (AOAC, 1990; codes 930.15; 942.05; 955.04). Moisture was determined by drying samples in an oven at 80 °C to constant weight. Protein content was determined following the AOAC method using an automated Kjeltech 2300 (Foss Tecator, Geneva, Switzerland). Lipid was determined by chloroform:methanol (2:1) extraction according to Folch, Lees, and Sloane-Stanley (1957) as modified by Ways and Hanahan (1964). The ash content was determined by incinerating samples

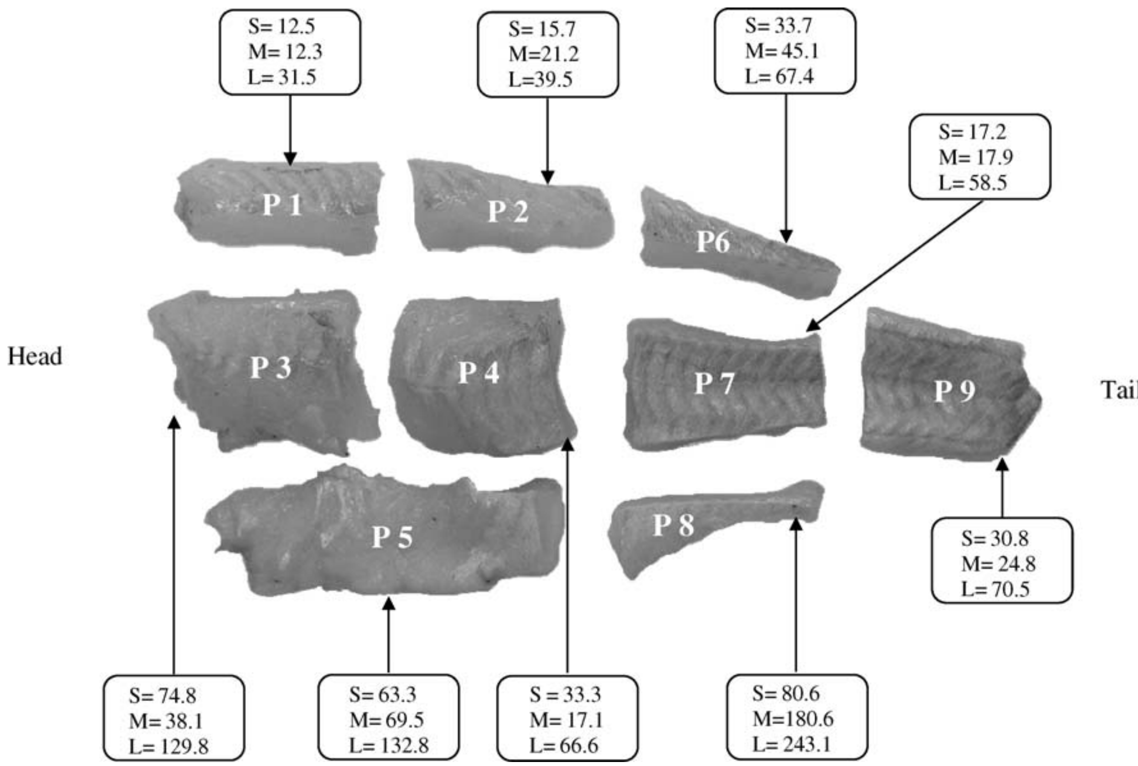

Fig. 1. The different portions of the left fillet of Murray cod used in the analysis. Please refer to the text for explanations on P1 to P9. The lipid contents (mg g^{-1}) for each fillet portion of small (S) medium (M) and large (L) sized fish are indicated.

(approximately 0.5 g) in a muffle furnace (Wit, C & L Tetlow, Australia) at 550 °C for 18 h. Nitrogen free extract (NFE), the soluble carbohydrate fraction in the feed, such as starch and sugar, was calculated by the difference (%NFE = %Dry matter – %Crude Protein – %Total Lipid – %ash). All analyses on muscle were performed in duplicate and diets in triplicate.

2.5. Fatty acid analysis of the lipids

After extraction, the fatty acids were esterified into methyl esters using the acid catalysed methylation method (Christie, 2003), and followed the methods previously used in the laboratory (De Silva et al., 2004; Francis et al., 2006). Briefly, 250 µl of ethyl 13:0 (5 mg ml^{-1}) (Sigma-Aldrich, Inc., St. Louis, MO, USA) was added to monitor the extent of transesterification, and 800 µl of 23:0 (2.5 mg ml^{-1}) as an internal standard (Sigma-Aldrich, Inc., St. Louis, MO, USA). Fatty acid methyl esters were isolated and identified using a Shimadzu GC 17A (Shimadzu, Chiyoda-ku, Tokyo, Japan) equipped with an Omegawax 250 capillary column (30 m × 0.25 mm internal diameter, 25 µm film thickness, Supelco, Bellefonte, PA, USA), a flame ionisation detector (FID), a Shimadzu AOC—20i auto injector, and a split injection system (split ratio 50:1). The temperature program was 150–180 °C at 3 °C min^{-1}, then from 180 to 250 °C at 2.5 °C min^{-1} and held at 250 °C for 10 min. The carrier gas was helium at 1.0 ml min^{-1}, at a constant flow. Each of the fatty acids was identified relative to known external standards. The resulting peaks were then corrected by the theoretical relative FID response factors (Ackman, 2002) and quantified relative to the internal standard.

For comparison of the whole fatty acid profile of the entire fillet and the different portions/tissues, the coefficient of distance D (McIntire, Tinsley, & Lowry, 1969) was computed using the equation:

$$D_{jh} = \left[\sum_{i=1}^{n}(P_{ij} - P_{ih})^2\right]^{1/2}$$

where, D_{jh} is the degree of difference (coefficient of distance) between samples j (“reference” Fillet) and h (“test” portion/tissue), P_{ij} and P_{ih} are percentage of fatty acid i in sample j and h, for each i fatty acid.

2.6. Statistical analysis

Data are reported as mean ± pooled SEM ($n = 6$). After normality and homogeneity of variance were confirmed, one way analysis of variance (ANOVA) was used to determine differences between means. Two way ANOVA was used to separate the effects of size, section and interaction of the two for data relative to proximate and fatty acid analyses. Differences were considered statistically significant at $P < 0.05$. Data were subject to Duncan’s post hoc test where differences were detected for homogenous subsets. All statistical analyses were performed using SPSS (SPSS Inc. Chicago, Illinois) v.11.5 for Windows.

Table 1
Proximate composition (mg g^{-1}), energy and fatty acid profile (% of total fatty acids) of the two commercial diets as fed (wet weight)

Proximate[a]	Diet[b]	
	9 mm	11 mm
Moisture	70.9 ± 1.3	65.8 ± 1.9
Protein	448 ± 1.4	447 ± 2.6
Lipid	210 ± 1.1	219 ± 2.2
Ash	79.0 ± 0.1	79.9 ± 0.2
NFE[c]	19.3 ± 0.1	18.9 ± 0.2
Energy[d]	22.2 ± 0.0	22.4 ± 0.0
Fatty acids		
14:0	5.01 ± 0.02	4.76 ± 0.02
16:0	21.2 ± 0.1	22.0 ± 0.1
18:0	5.56 ± 0.02	5.74 ± 0.02
16:1$n-7$	6.80 ± 0.022	6.84 ± 0.02
18:1$n-9$	23.1 ± 0.1	24.9 ± 0.1
18:1$n-7$	2.79 ± 0.01	2.79 ± 0.01
20:1[e]	1.10 ± 0.01	1.06 ± 0.01
18:2$n-6$	8.03 ± 0.04	8.04 ± 0.03
20:4$n-6$	0.72 ± 0.01	0.67 ± 0.00
18:3$n-3$	1.14 ± 0.01	1.14 ± 0.00
18:4$n-3$	1.55 ± 0.02	1.39 ± 0.01
20:5$n-3$	9.46 ± 0.03	8.45 ± 0.04
22:5$n-3$	1.11 ± 0.00	1.00 ± 0.01
22:6$n-3$	6.68 ± 0.04	6.02 ± 0.03
$\sum$ SFA	33.2 ± 0.1	33.8 ± 0.1
$\sum$ MUFA	34.7 ± 0.2	36.2 ± 0.1
$\sum$ PUFA	31.8 ± 0.1	29.5 ± 0.1
$\sum$ HUFA	18.8 ± 0.1	16.9 ± 0.1
$\sum n-3$ PUFA	20.4 ± 0.1	18.4 ± 0.1
$\sum n-6$ PUFA	9.34 ± 0.03	9.26 ± 0.03
$\sum n-3$ HUFA	17.7 ± 0.1	15.9 ± 0.07
$\sum n-6$ HUFA	1.09 ± 0.01	1.03 ± 0.00
$n-3/n-6$	2.19 ± 0.00	1.99 ± 0.00

[a] Moisture, protein, lipid and ash expressed as mg g^{-1}. Energy expressed as kJ g^{-1}.
[b] Skretting Nova ME, Tasmania, Australia.
[c] NFE = nitrogen free extract – calculated by difference, see text for details.
[d] Calculated on the basis of 23.6, 39.5 and 17.2 kJ g^{-1} of protein, fat and carbohydrate, respectively.
[e] 20:1 represents the sum of 20:1$n-9$ and 20:1$n-11$.

3. Results

3.1. Diet composition

The proximate compositions of the two diets were very similar as expected (Table 1). The three major classes of fatty acids, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), and the $n-3$ fatty acids (i.e. EPA and DHA) also did not show noteworthy differences.

3.2. Biometric parameters

The biometric data for the three fish sizes are given in Table 2. Small fish had the lowest condition factor ($P < 0.05$). The hepatosomatic index (HSI) did not show any significant difference and ranged between 1.2% and 1.3%. Fillet yield was 38.6%, 41.8%, and 41.0% in small, medium and large fish, respectively and was significantly higher ($P < 0.05$) in medium fish. Dress-out percentage did not differ significantly between size classes ($P > 0.05$).

Table 2
Biometric data and yields of the three size classes of Murray cod used for this study

	Fish size		
	Small	Medium	Large
Length[a]	26.7 ± 0.3[a]	34.0 ± 0.5[b]	47.6 ± 1.1[c]
Total weight[a]	284.8 ± 10.7[a]	692.0 ± 40.0[b]	1824 ± 179[c]
Somatic weight[a]	255.5 ± 10.2[a]	624.6 ± 37.2[b]	1674 ± 192[c]
Fillet weight[a]	55.3 ± 3.5[a]	144.9 ± 9.7[b]	375.2 ± 39.5[c]
Viscera weight[a]	28.3 ± 1.3[a]	67.1 ± 4.6[b]	96.5 ± 4.2[c]
Liver weight[a]	3.5 ± 0.4[a]	9.2 ± 1.5[a]	23.0 ± 3.6[b]
Visceral fat weight[a]	11.5 ± 1.0[a]	35.3 ± 3.2[a]	75.1 ± 14.3[b]
K[b]	1.5 ± 0.0[a]	1.8 ± 0.0[b]	1.7 ± 0.1[b]
HSI[c,d]	1.2 ± 0.1	1.3 ± 0.1	1.2 ± 0.1
VFI[c,e]	4.1 ± 0.4	5.2 ± 0.6	4.1 ± 0.7
Dress-out percentage[c]	89.7 ± 0.4	90.2 ± 0.6	91.1 ± 1.6
Fillet yield[c]	38.6 ± 0.5[a]	41.8 ± 0.4[b]	41.0 ± 0.5[ab]

Values with the same superscript in each row are not significantly different ($P > 0.05$).
[a] Value in g.
[b] Condition factor.
[c] Value in %.
[d] Hepatosomatic index.
[e] Visceral fat index.

3.3. Proximate composition of fillet portions, whole fillet and liver

The moisture, protein, lipid, ash and energy contents of the nine fillet portions, whole fillet and liver are given in Table 3. There was considerable variability in lipid content amongst all fillet portions. Lipid content in P8 was the highest in all fish sizes and increased with increasing fish size, ranging between 80.6 and 243.1 mg g^{-1}. On the other hand, P1 had the lowest, with 12.5, 12.28 and 31.5 mg g^{-1} in small, medium and large fish, respectively. Energy content of muscle portions was directly proportional to the lipid content and was highest in P8, ranging between 7.3 kJ g^{-1} (small) and 13.2 kJ g^{-1} (large), and lowest in P1, ranging between 5.0 kJ g^{-1} (small) and 5.7 kJ g^{-1} (large).

Moisture was linearly and inversely proportional ($R^2 = 0.97$, $P < 0.05$) to the lipid content amongst the fillet portions as shown in Fig. 2a and Table 9. The lowest values were observed in P8 with 593.3, 641.9 and 735.4 mg g^{-1} in large, medium and small fish, respectively.

Muscle protein content was also inversely proportional to the lipid content across fillet portions in all fish sizes ($R^2 = 0.56$, $P < 0.05$), and was highest in P1 and the lowest in P8. The liver had the lowest ($P < 0.05$) protein content of all tissues.

Both size and portion (and an interaction of both) seemed to have an effect on the proximate composition of the fish (Table 4).

Table 3
Proximate composition (mg g^{-1}) (w/w basis) and energy content (kJ g^{-1}) of the fillet portions (P1 to P9), whole fillet (right) and the liver of Murray cod of three sizes

	Body sections											Pooled SEM
	P1	P2	P3	P4	P5	P6	P7	P8	P9	Fillet	Liver	
Small												
Moisture	786.5^{cd}	786.6^{cd}	737.6^{a}	771.2^{cd}	748.8^{ab}	773.9^{cd}	789.2^{d}	735.4^{a}	779.8^{cd}	774.1^{cd}	764.1^{bc}	5.76
Protein	189.6^{d}	186.2^{cd}	176.9^{bc}	183.2^{bcd}	176.2^{bc}	181.8^{bcd}	182.8^{bcd}	173.9^{b}	179.1^{bcd}	177.3^{bc}	133.8^{a}	2.46
Lipid	12.5^{a}	15.7^{a}	74.8^{bc}	33.3^{a}	63.3^{b}	33.7^{a}	17.2^{a}	80.6^{bc}	30.8^{a}	35.7^{a}	89.4^{c}	5.26
Ash	11.4^{abc}	11.5^{abc}	14.8^{d}	12.4^{bc}	11. 7^{abc}	10.6^{ab}	10.8^{ab}	10.1^{a}	10.4^{a}	12.9^{c}	12.8^{c}	0.50
Energy[a]	5.0^{a}	5.0^{a}	7.1^{b}	5.4^{a}	6.7^{b}	5.6^{a}	5.0^{a}	7.3^{b}	5.4^{a}	5.6^{a}	6.7^{b}	0.19
Medium												
Moisture	786.4^{b}	789.4^{b}	766.2^{b}	787.0^{b}	739.3^{b}	743.4^{b}	788.7^{b}	641.9^{a}	783.5^{b}	760.7^{b}	787.8^{b}	10.99
Protein	190.7^{d}	178.6^{c}	180.8^{cd}	183.9^{cd}	180.8^{cd}	178.0^{c}	182.8^{cd}	163.8^{b}	181.2^{cd}	178.1^{b}	115.8^{a}	3.30
Lipid	12.3^{a}	21.2^{a}	38.1^{ab}	17.1^{a}	69.5^{bc}	45.1^{abc}	17.9^{a}	180.6^{d}	24.8^{a}	50.6^{abc}	84.4^{c}	11.90
Ash	10.7^{ab}	10.8^{ab}	14.9^{c}	12.0^{b}	10.4^{ab}	10.4^{ab}	10.6^{ab}	9.7^{a}	10.5^{ab}	10.7^{ab}	12.0^{b}	0.50
Energy[a]	5.0^{a}	5.1^{a}	5.8^{ab}	5.0^{a}	7.0^{b}	5.9^{ab}	5.0^{a}	10.0^{c}	5.3^{a}	6.2^{ab}	6.1^{ab}	0.40
Large												
Moisture	766.6^{de}	761.4^{de}	688.2^{b}	738.7^{cd}	690.7^{bc}	737.6^{cd}	752.5^{de}	593.3^{a}	744.9^{de}	698.6^{b}	794.6^{e}	11.30
Protein	189.8^{f}	186.4^{ef}	168.1^{cd}	183.8^{ef}	173.6^{de}	175.8^{def}	178.5^{def}	151.2^{b}	173.6^{de}	167.4^{bc}	125.0^{a}	3.37
Lipid	31.5^{a}	39.5^{a}	129.8^{b}	66.5^{a}	132.8^{b}	67.4^{a}	58.5^{a}	243.1^{c}	70.5^{a}	119.6^{b}	68.6^{a}	12.60
Ash	12.1^{ab}	12.6^{ab}	13.8^{b}	11.0^{ab}	11.8^{ab}	10.6^{ab}	10.6^{a}	12.4^{ab}	11.0^{ab}	13.4^{ab}	11.6^{ab}	0.46
Energy[a]	5.7^{a}	6.0^{ab}	9.1^{cd}	7.0^{abc}	9.0^{cd}	9.9^{d}	6.5^{ab}	13.2^{e}	6.9^{abc}	8.7^{bcd}	5.7^{a}	0.59

Values are mean ± pooled SEM.
Values with the same superscript in each row are not significantly different ($P > 0.05$).
Values are average of 12 fish (small) and 6 fish (medium and large).
Moisture, protein, lipid and ash expressed as mg g^{-1}. Energy expressed as kJ g^{-1}.
[a] Calculated on the basis of 23.6, 39.5 and 17.2 kJ g^{-1} of protein, fat and carbohydrate, respectively.

3.4. Fatty acid composition of the portions, whole fillet, liver and perivisceral fat

Fatty acid composition of the nine fillet portions, whole fillet, liver and perivisceral fat are given in Tables 5–7. The total fatty acid concentration ranged between 568 (P1) to 864 mg g $lipid^{-1}$ (P8), 612 (P1) to 805 mg g $lipid^{-1}$ (P5) and 730 (P1) to 860 mg g $lipid^{-1}$ (P3), in small, medium and large sized fish, respectively. The highest concentration of SFA was found in P1, mainly in the form of palmitic acid (16:0) and stearic acid (18:0). The percent Palmitic acid in P1 was 21.6%, 22.6% and 21.9% in small, medium and large sized fish, respectively. Oleic acid (18:1 $n-9$) contributed the most to the total concentration of MUFA across all size groups. The highest concentration of individual monoenes was found in P8. However, in small sized fish, oleic acid was found in higher concentrations in P5 (24.5%). The concentration of MUFA in the perivisceral fat was higher than any other major fatty acid class, ranging from 34.0% in large fish to 37.1% in small fish. The same was found in the fillet and ranged between 33.3% in medium and 34.00% in small fish.

Polyunsaturated fatty acids (PUFA) occurred in highest concentration, ranging between 34.9% and 42.6% in large and small fish, respectively. The major contributors to $n-3$ and $n-6$ highly unsaturated fatty acids (HUFA) were, eicosapentaenoic acid, (EPA, 20:5$n-3$), docosahexaenoic acid (DHA, 22:6$n-3$) and arachidonic acid (ArA, 20:4$n-6$), and these were found in higher concentrations in P1.

The coefficient of distance (D) between the whole filet and the fillet portions was highest in P1 amongst the nine portions and different sized fish. The lowest values were recorded in P9 (2.24), P6 (1.08) and P5 (1.22) in small, medium and large fish, respectively.

Overall, MUFA tended to increase exponentially (R^2= 0.86), PUFA to decrease exponentially ($R^2 = 0.86$), while SFA remained unchanged ($R^2 = 0.01$) with increasing levels of lipid (Fig. 2b). Fatty acids of the $n-3$ class (EPA, DHA, LnA) decreased exponentially with increasing levels of lipid, whereas $n-6$ fatty acids (ArA, LA) increased exponentially up to about 2% lipid and then plateaued (Fig. 2c and d). The correspondent equations and regression coefficients are given in Table 9.

The results of the two way ANOVA showed that the general fatty acid composition seemed to be influenced by fish size and fillet portions and, to a lesser extent, by the combination of the two (Table 8).

4. Discussion

It is important, when conducting nutritional experiments or eating quality assessments that the samples analysed are representative of the whole animal. An inaccurate choice of samples can compromise the final outcome of an otherwise well designed experiment and invalidate its results (Burns, 1994). Moreover, from a consumer point of view, with the recent emphasis placed on the importance of $n-3$ polyunsaturated fatty acids on human nutrition (Arts, Ackman, & Holub, 2001; Connor, 2000; Kris-Etherton, Harris,

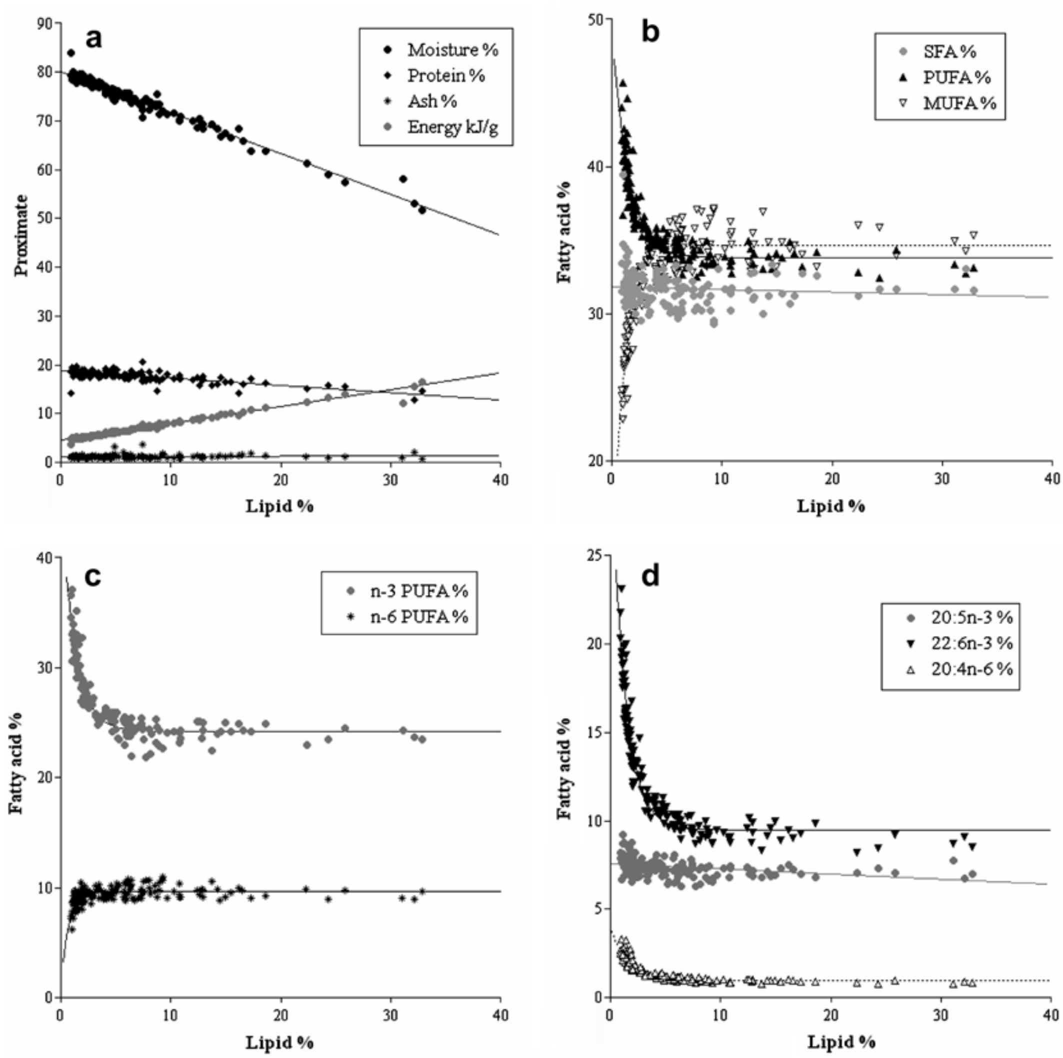

Fig. 2. The relationship between (a) lipids and proximate composition of the muscle portions, (b) lipids and the percentage SFA, MUFA and PUFA content of the muscle portions, (c) lipids and the percentage $n-3$ and $n-6$ PUFA content of the muscle portions, and (d) lipids and the percentage Ara, EPA and DHA content of the muscle portions. In all cases the lines of best fit are given.l

Table 4
Two way ANOVA for size and portion effects (and combination of both) on the proximate composition of the different fillet portions of Murray cod

	Size		Portion		Size × portion	
	F value	*P*	*F* value	*P*	*F* value	*P*
Moisture	37.105	***	27.859	***	3.885	***
Protein	7.919	**	70.830	***	1.897	*
Lipid	46.180	***	31.053	***	4.591	***
Ash	5.693	**	3.552	***	2.057	**
Energy	47.482	***	19.517	***	3.298	***

$P^{***} \leqslant 0.001$, $^{**} \leqslant 0.01$, $^{*} \leqslant 0.05$.

& Appel, 2002; Larsson, Kumlin, Ingelman-Sundberg, & Wolk, 2004; Pike, 1999), it is important to know the $n-3$ content of farmed fish and what portion of a fish is nutritionally more beneficial than others. Such information could be important from a market point of view, and also indirectly to the culturist to enable him to improve the final eating quality of his product.

From the present study, it is evident that there are marked differences in lipid and fatty acid deposition in different portions of the fillet of farmed Murray cod. Fish used in this study were fed nutritionally similar diets, and as such, differences between fish or fish of different size groups cannot be attributed to the feed. Lipid distribution within the fillet varied depending on the size of the fish, portion analysed and interaction of both. Generally, the ventral (P5 and P8) and the frontal-lateral portions (P3) had a higher concentration of crude lipid and lower amount of moisture. This is in agreement with previous studies on Atlantic salmon and lake trout (Aursand, Bleivick, Rainuzzo, Jørgensen, & Mohr, 1994; Kinsella, Shimp, Mai, & Weihrauch, 1977). There was also an increased fat deposition as the fish size increased, suggesting that Murray cod utilises lipid at a faster rate during early growth stages, and then starts accumulating fat as growth decreases. This is in accordance with that described by Morris (2001) for Atlantic salmon. From a nutritional

Table 5
Fatty acid composition (% of total fatty acids) of different portions/tissues of small sized Murray cod

Fatty acid	Small fish Fish portion/tissue												Pooled SEM
	P1	P2	P3	P4	P5	P6	P7	P8	P9	Fillet	Liver	Fat	
14:0	2.8^{a}	3.4^{b}	4.7^{de}	4.2^{c}	4.7^{de}	4.1^{c}	3.5^{b}	4.9^{e}	4.0^{c}	4.3^{cd}	3.4^{b}	5.0^{e}	0.140
16:0	21.6^{f}	21.2^{ef}	20.2^{bc}	20.9^{def}	20.5^{cd}	20.9^{def}	21.3^{ef}	20.4^{cd}	20.8^{cde}	20.5^{cd}	19.3^{a}	19.6^{ab}	0.181
18:0	7.5^{e}	6.7^{d}	4.5^{a}	5.5^{c}	4.8^{ab}	5.7^{c}	6.4^{d}	4.7^{ab}	5.6^{c}	5.2^{bc}	5.7^{c}	4.6^{a}	0.177
$16{:}1n-7$	3.9^{a}	4.8^{b}	7.0	6.1^{de}	6.9^{f}	6.0^{de}	5.1^{bc}	7.1^{f}	6.0^{de}	6.3^{e}	5.5^{cd}	7.0^{f}	0.184
$18{:}1n-9$	18.3^{a}	19.8^{b}	24.4^{de}	22.8^{c}	24.5^{de}	22.5^{c}	20.9^{b}	24.4^{de}	22.7^{c}	23.6^{cd}	23.3^{cd}	25.7^{e}	0.449
$18{:}1n-7$	2.8^{a}	2.98^{a}	3.3^{a}	3.2^{a}	2.8^{a}	3.2^{a}	3.0^{a}	3.4^{a}	3.2^{a}	3.3^{a}	2.7^{a}	3.5^{a}	0.142
20:1[a]	0.7^{a}	0.8^{ab}	0.9^{cd}	0.8^{bcd}	0.8^{bcd}	0.8^{bcd}	0.9^{bc}	0.8^{bcd}	0.8^{bcd}	0.9^{cd}	0.9^{cd}	1.0^{cd}	0.045
$18{:}2n-6$	6.1^{a}	6.9^{b}	8.8^{de}	8.0^{c}	8.8^{de}	8.0^{c}	7.2^{b}	8.9^{de}	8.0^{c}	8.4^{cd}	8.0^{c}	9.2^{e}	0.185
$20{:}4n-6$	2.9^{f}	2.2^{e}	1.0^{ab}	1.7^{d}	1.0^{ab}	1.5^{cd}	2.1^{e}	0.9^{ab}	1.5^{cd}	1.3^{bc}	1.4^{cd}	0.8^{a}	0.109
$18{:}3n-3$	0.9^{a}	1.1^{ab}	1.2^{b}	1.2^{ab}	1.2^{b}	1.0^{ab}	1.0^{ab}	1.3^{b}	1.1^{ab}	1.1^{ab}	1.0^{ab}	1.3^{b}	0.054
$18{:}4n-3$	1.1^{ab}	1.2^{ab}	1.5^{c}	1.3^{ab}	1.5^{c}	1.3^{bc}	1.1^{ab}	1.5^{c}	1.2^{abc}	1.3^{bc}	1.0^{a}	1.5^{c}	0.064
$20{:}5n-3$	7.5^{e}	7.4^{e}	6.8^{cd}	7.0^{cde}	6.7^{c}	7.1^{cde}	7.3^{de}	6.7^{c}	6.9^{cde}	6.8^{c}	5.2^{a}	6.2^{b}	0.148
$22{:}5n-3$	4.5^{cd}	4.2^{bc}	3.8^{a}	3.9^{ab}	3.8^{a}	4.0^{ab}	4.0^{ab}	3.8^{a}	3.9^{ab}	3.9^{a}	4.6^{d}	3.9^{a}	0.092
$22{:}6n-3$	19.8^{e}	16.7^{d}	9.4^{ab}	12.4^{c}	9.7^{ab}	12.4^{c}	15.1^{d}	9.3^{ab}	12.6^{c}	11.2^{bc}	15.3^{d}	8.4^{a}	0.654
∑ SFA	31.8^{f}	31.3^{ef}	29.5^{bc}	30.7^{de}	30.0^{bcd}	30.1^{de}	31.3^{ef}	29.9^{bcd}	30.4^{cde}	30.1^{bcd}	28.4^{a}	29.2^{ab}	0.266
∑ MUFA	25.2^{a}	28.0^{b}	35.6^{ef}	32.8^{cd}	35.1^{def}	32.4^{c}	29.5^{b}	35.6^{ef}	32.6^{cd}	34.0^{cde}	32.4^{c}	37.2^{f}	0.662
∑ PUFA	42.6^{g}	39.4^{f}	32.5^{ab}	35.0^{cd}	32.7^{ab}	35.2^{cd}	37.8^{ef}	32.5^{ab}	35.2^{cd}	33.9^{bc}	36.4^{de}	31.2^{a}	0.670
∑ HUFA	34.6^{g}	30.5^{f}	21.0^{ab}	25.0^{cd}	21.2^{ab}	24.9^{cd}	28.5^{ef}	20.8^{ab}	24.9^{cd}	23.0^{bc}	26.4^{de}	19.2^{a}	0.891
∑ $n-3$ PUFA	33.6^{g}	30.3^{f}	22.7^{ab}	25.3^{cd}	22.9^{ab}	25.7^{cd}	28.5^{ef}	22.6^{ab}	25.8^{cd}	24.2^{bc}	26.9^{de}	21.2^{a}	0.714
∑ $n-6$ PUFA	9.0^{a}	9.1^{ab}	9.8^{de}	9.7^{cde}	9.8^{de}	9.5^{bcd}	9.29^{abc}	9.8^{de}	9.4^{abcd}	9.7^{cde}	9.4^{abcd}	10.0^{e}	0.128
∑ $n-3$ HUFA	31.7^{g}	28.3^{f}	20.0^{ab}	23.3^{cd}	20.2^{ab}	23.4^{cd}	26.4^{ef}	19.8^{ab}	23.5^{cd}	21.8^{bc}	25.0^{de}	18.4^{a}	0.790
∑ $n-6$ HUFA	2.9^{f}	2.2^{e}	1.0^{b}	1.7^{d}	1.0^{bc}	1.5^{d}	2.1^{e}	0.9^{ab}	1.5^{d}	1.26^{cd}	1.4^{d}	0.8^{a}	0.109
$n-3/n-6$	3.73^{h}	3.35^{g}	2.33^{abc}	2.62^{cde}	2.33^{abc}	2.73^{de}	3.09^{fg}	2.31^{ab}	2.74^{de}	2.51^{bcd}	2.86^{ef}	2.13^{a}	0.100
Total FA[b]	568.2^{a}	614.1^{ab}	837.0^{efg}	697.4^{bcd}	823.1^{efg}	745.9^{cdef}	670.5^{abc}	863.7^{g}	737.5^{cde}	769.5^{cdefg}	786.6^{defg}	853.1^{fg}	3.379
D	11.29^{d}	7.48^{c}	2.42^{a}	2.70^{a}	2.44^{a}	3.37^{ab}	5.54^{bc}	2.51^{a}	2.24^{a}	–	5.40^{bc}	4.08^{ab}	0.413

All values are mean of 12 fish.
Values in the same row with the same superscripts are not significantly different ($P < 0.05$).
[a] 20:1 represents the sum of $20{:}1n-9$ and $20{:}1n-11$.
[b] Total FA (%) per g of lipid.

Table 6
Fatty acid composition (% of total fatty acids) of different portions/tissues of medium sized Murray cod

Fatty acid	Medium fish Fish portion/tissue												Pooled SEM
	P1	P2	P3	P4	P5	P6	P7	P8	P9	Fillet	Liver	Fat	
14:0	3.7^{ab}	4.0^{abc}	4.3^{bc}	4.1^{bc}	5.3^{d}	5.1^{d}	3.9^{abc}	5.6^{d}	4.4^{c}	5.1^{d}	3.3^{a}	5.7^{d}	0.19
16:0	22.6^{d}	21.8^{cd}	21.2^{bc}	21.5^{bcd}	21.1^{bc}	21.1^{bc}	21.6^{bcd}	20.9^{bc}	21.3^{bc}	21.0^{bc}	19.4^{bc}	20.6^{b}	0.31
18:0	7.1^{c}	6.5^{bc}	5.9^{b}	6.1^{b}	4.7^{a}	5.0^{a}	6.4^{bc}	4.5^{a}	5.9^{b}	5.0^{a}	4.9^{a}	4.5^{a}	0.21
16:1$n-7$	4.7^{a}	5.4^{ab}	6.0^{b}	5.7^{b}	7.5^{c}	7.3^{c}	5.4^{ab}	7.8^{c}	6.2^{b}	7.15^{c}	6.1^{b}	7.7^{c}	0.24
18:1$n-9$	17.7^{a}	18.7^{ab}	20.1^{bcd}	19.4^{bc}	22.2^{e}	21.8^{de}	18.9^{ab}	22.7^{e}	20.4^{bcd}	21.7^{cde}	22.6^{e}	22.6^{e}	0.49
18:1$n-7$	2.8^{a}	3.0^{ab}	3.1^{abc}	3.1^{bcde}	3.3^{cdef}	3.3^{cde}	2.9^{ab}	3.4^{def}	3.1^{abcd}	3.3^{cde}	3.6^{f}	3.4^{ef}	0.07
20:1[a]	0.9^{abcd}	0.8^{a}	1.0^{abcd}	0.9^{abcd}	1.1^{bcde}	1.1^{cde}	0.9^{ab}	1.1^{e}	0.9^{abc}	1.1^{de}	1.2^{e}	1.2^{e}	0.04
18:2$n-6$	5.3^{a}	5.9^{ab}	6.5^{bc}	6.0^{b}	7.5^{e}	7.3^{de}	6.0^{ab}	7.8^{e}	6.6^{bcd}	7.3^{cde}	6.5^{bcd}	7.7^{e}	0.23
20:4$n-6$	2.3^{e}	1.9^{de}	1.7^{cd}	1.8^{cd}	1.0^{ab}	1.1^{ab}	2.0^{de}	0.8^{a}	1.6^{cd}	1.1^{ab}	1.4^{bc}	0.8^{a}	0.11
18:3$n-3$	0.8^{a}	0.9^{b}	1.0^{bcd}	0.9^{bc}	1.1^{de}	1.1^{cde}	0.9^{b}	1.2^{e}	0.9^{bc}	1.1^{cde}	0.8^{ab}	1.2^{e}	0.05
18:4$n-3$	0.9^{a}	1.1^{ab}	1.3^{b}	1.3^{b}	1.6^{c}	1.6^{c}	1.1^{ab}	1.7^{c}	1.3^{b}	1.6^{c}	1.0^{a}	1.8^{c}	0.07
20:5$n-3$	7.7^{b}	8.0^{b}	7.9^{b}	8.1^{b}	7.6^{b}	7.7^{b}	8.2^{b}	7.5^{b}	7.9^{b}	7.7^{b}	5.0^{a}	7.6^{b}	0.30
22:5$n-3$	4.3^{a}	4.2^{a}	4.2^{a}	4.2^{a}	4.0^{a}	4.1^{a}	4.4^{a}	4.0^{a}	4.2^{a}	4.1^{a}	5.5^{b}	4.1^{a}	0.10
22:6$n-3$	17.7^{d}	15.8^{cd}	13.8^{bc}	14.9^{bc}	9.7^{a}	10.1^{a}	15.4^{bcd}	8.8^{a}	12.9^{b}	10.4^{a}	16.1^{cd}	8.7^{a}	0.73
$\sum$ SFA	33.3^{c}	32.3^{bc}	31.4^{b}	31.7^{bc}	31.1^{b}	31.2^{b}	31.9^{bc}	31.0^{b}	31.6^{b}	31.1^{b}	27.6^{a}	30.7^{b}	0.42
$\sum$ MUFA	26.1^{a}	28.0^{ab}	30.1^{b}	29.1^{b}	34.0^{d}	33.4^{cd}	28.2^{ab}	35.0^{d}	30.5^{bc}	33.3^{cd}	33.4^{cd}	34.8^{d}	0.77
$\sum$ PUFA	38.8^{d}	37.8^{cd}	36.4^{cd}	37.2^{cd}	32.5^{a}	33.0^{ab}	38.0^{cd}	31.8^{a}	35.4^{bc}	33.1^{ab}	36.3^{cd}	31.9^{a}	0.81
$\sum$ HUFA	32.0^{c}	29.9^{bc}	27.6^{b}	29.0^{bc}	22.3^{a}	23.0^{a}	23.0^{bc}	21.1^{a}	26.7^{b}	23.4^{a}	28.0^{b}	21.3^{a}	0.97
$\sum n-3$ PUFA	31.2^{c}	30.0^{bc}	28.2^{b}	29.3^{bc}	24.0^{a}	24.6^{a}	30.0^{bc}	23.2^{a}	27.3^{b}	24.9^{a}	28.4^{b}	23.4^{a}	0.81
$\sum n-6$ PUFA	7.5^{a}	7.8^{ab}	8.2^{bcd}	7.8^{ab}	8.5^{cd}	8.4^{bcd}	8.0^{abcd}	8.6^{d}	8.2^{bcd}	8.4^{bcd}	7.9^{abc}	8.5^{cd}	0.16
$\sum n-3$ HUFA	29.7^{c}	28.0^{bc}	25.9^{b}	27.2^{bc}	21.3^{a}	21.9^{a}	28.0^{bc}	20.3^{a}	25.1^{b}	22.3^{a}	26.6^{bc}	20.5^{a}	0.87
$\sum n-6$ HUFA	2.3^{f}	1.9^{def}	1.7^{de}	1.8^{def}	1.0^{ab}	1.1^{ab}	2.0^{ef}	0.8^{a}	1.6^{de}	1.1^{bc}	1.4^{cd}	0.8^{a}	0.11
$n-3/n-6$	4.19^{d}	3.86^{cd}	3.45^{b}	3.78^{cd}	2.8^{a}	2.9^{a}	3.76^{cd}	2.7^{a}	3.3^{b}	2.97^{a}	3.6^{b}	2.76^{a}	0.13
Total FA[b]	611.8^{a}	636.5^{ab}	674.3^{abc}	669.6^{ab}	804.5^{de}	704.5^{abc}	650.5^{abc}	789.6^{abc}	749.1^{abc}	726.4^{abc}	761.4^{cde}	848.0^{c}	3.25
D	9.76^{e}	7.33^{de}	5.31^{bcd}	6.20^{cd}	1.33^{a}	1.08^{a}	6.57^{cd}	2.37^{ab}	3.49^{abc}	–	7.47^{de}	2.4^{ab}	0.441

All values are mean of 6 fish.
Values in the same row with the same superscripts are not significantly different ($P < 0.05$).
[a] 20:1 represents the sum of 20:1$n-9$ and 20:1$n-11$.
[b] Total FA (%) per g of lipid.

Table 7
Fatty acid composition (% of total fatty acids) of different portions/tissues of large sized Murray cod

Fatty acid	Large fish Fish portion/tissue												Pooled SEM
	P1	P2	P3	P4	P5	P6	P7	P8	P9	Fillet	Liver	Fat	
14:0	4.8^{b}	5.1^{bc}	5.7^{cdef}	5.5^{cdef}	5.8^{def}	5.4^{bcde}	5.4^{bcdef}	6.1^{f}	5.2^{bcd}	5.8^{cdef}	3.3^{a}	6.0^{ef}	0.19
16:0	21.9^{d}	21.8^{cd}	21.2^{cd}	21.3^{cd}	21.3^{cd}	21.6^{cd}	21.3^{cd}	21.0^{c}	21.6^{cd}	21.2^{cd}	19.2^{a}	20.1^{b}	0.23
18:0	5.3^{c}	5.1^{bc}	4.4^{a}	4.6^{ab}	4.4^{a}	4.9^{abc}	4.7^{ab}	4.3^{a}	4.9^{abc}	4.4^{a}	5.6^{d}	4.5^{a}	0.16
16:1$n-7$	6.8^{b}	7.3^{bc}	8.0^{de}	7.8^{cde}	8.1^{de}	7.6^{cd}	7.7^{cde}	8.3^{e}	7.5^{bcd}	8.1^{de}	5.5^{a}	7.7^{cde}	0.18
18:1$n-9$	19.8	20.1	20.6	21.0	20.5	20.4	20.8	21.0	20.6	20.9	20.7	21.3	0.52
18:1$n-7$	3.2^{a}	3.4^{ab}	3.5^{bc}	3.5^{bc}	3.5^{bc}	3.4^{ab}	3.5^{bc}	3.5^{bc}	3.4^{b}	3.5^{bc}	3.4^{bc}	3.6^{c}	0.05
20:1[a]	1.1^{a}	1.1^{a}	1.1^{a}	1.1^{a}	1.2^{ab}	1.1^{a}	1.0^{a}	1.2^{ab}	1.1^{a}	1.2^{a}	1.0^{a}	1.4^{b}	0.07
18:2$n-6$	7.0^{b}	7.2^{bc}	7.7^{cd}	7.7^{cd}	7.6^{cd}	7.4^{bcd}	7.6^{cd}	7.9^{d}	7.4^{bcd}	7.7^{cd}	6.7^{a}	7.8^{cd}	0.18
20:4$n-6$	1.6^{d}	1.4^{cd}	1.1^{ab}	1.1^{ab}	1.0^{ab}	1.2^{bc}	1.3^{bc}	0.9^{a}	1.2^{bc}	1.0^{ab}	1.6^{d}	0.9^{a}	0.07
18:3$n-3$	1.0^{b}	1.1^{bc}	1.2^{de}	1.2^{cde}	1.2^{de}	1.2^{cd}	1.2^{cde}	1.3^{e}	1.1^{bcd}	1.2^{de}	0.9^{a}	1.2^{cde}	0.03
18:4$n-3$	1.4^{b}	1.4^{bc}	1.6^{de}	1.5^{bcde}	1.6^{de}	1.5^{bcd}	1.5^{bcd}	1.7^{e}	1.5^{bcd}	1.6^{de}	1.0^{a}	1.6^{cde}	0.04
20:5$n-3$	7.6^{d}	7.4^{cd}	7.3^{cd}	7.3^{cd}	7.1^{bcd}	7.3^{cd}	7.4^{cd}	7.0^{bc}	7.4^{cd}	7.2^{bcd}	5.4^{a}	6.7^{b}	0.12
22:5$n-3$	4.2^{a}	4.1^{a}	4.1^{a}	4.1^{a}	4.1^{a}	4.1^{a}	4.0^{a}	4.1^{a}	4.1^{a}	4.1^{a}	5.3^{b}	4.4^{a}	0.09
22:6$n-3$	12.2^{c}	11.3^{bc}	9.8^{ab}	9.9^{ab}	9.6^{ab}	10.4^{ab}	10.2^{ab}	9.0^{a}	10.6^{abc}	9.4^{a}	17.6^{d}	9. 8^{ab}	0.43
$\sum$ SFA	32.0^{c}	32.0^{c}	31.3^{bc}	31.3^{bc}	31.6^{bc}	31.9^{c}	31.3^{bc}	31.4^{bc}	31.7^{bc}	31.4^{bc}	28.1^{a}	30.6^{b}	0.33
$\sum$ MUFA	31.0^{a}	31.8^{ab}	33.2^{bc}	33.2^{bc}	33.4^{bc}	32.5^{bc}	32.9^{bc}	34.1^{c}	32.5^{bc}	33.6^{c}	30.6^{a}	34.0^{c}	0.51
$\sum$ PUFA	34.9^{d}	34.0^{cd}	32.8^{abc}	32.8^{abc}	32.3^{ab}	33.1^{abc}	33.2^{abc}	31.8^{a}	33.3^{bc}	32.2^{ab}	38.3^{e}	32.4^{ab}	0.45
$\sum$ HUFA	25.5^{d}	24.2^{cd}	22.2^{ab}	22.4^{ab}	21.8^{ab}	23.1^{bc}	22.9^{bc}	21.0^{a}	23.2^{bc}	21.6^{ab}	29.8^{e}	21.8^{ab}	0.54
$\sum$ $n-3$ PUFA	26.4^{d}	25.4^{cd}	24.0^{abc}	24.0^{abc}	23.7^{ab}	24.5^{bc}	24.3^{abc}	23.0^{a}	24.6^{bc}	23.5^{ab}	30.1^{e}	23.7^{ab}	0.44
$\sum$ $n-6$ PUFA	8.5^{ab}	8.6^{ab}	8.8^{b}	8.8^{b}	8.6^{ab}	8.6^{ab}	8.9^{b}	8.7^{b}	8.7^{ab}	8.7^{b}	8.2^{a}	8.6^{ab}	0.15
$\sum$ $n-3$ HUFA	23.9^{d}	22.8^{cd}	21.2^{ab}	21.2^{ab}	20.8^{ab}	21.9^{bc}	21.6^{bc}	20.1^{a}	22.0^{bc}	20.7^{ab}	28.3^{e}	20.9^{ab}	0.47
$\sum$ $n-6$ HUFA	1.5^{f}	1.4^{ef}	1.1^{bcd}	1.1^{cd}	1.0^{abc}	1.2^{cde}	1.25^{de}	0. 9^{ab}	1.2^{de}	1.0^{abc}	1.6^{f}	0.9^{a}	0.07
$n-3/n-6$	3.10^{c}	2.95^{bc}	2.74^{ab}	2.74^{ab}	2.75^{ab}	2.86^{abc}	2.75^{ab}	2.64^{a}	2.85^{ab}	2.70^{ab}	3.69^{d}	2.76^{ab}	0.079
Total FA[b]	729.5^{a}	777.6^{ab}	859.7^{bc}	830.4^{bc}	847.1^{bc}	844.5^{bc}	831.0^{bc}	835.0^{bc}	846.9^{bc}	847.5^{bc}	765.8^{ab}	903.7^{c}	2.79
D	3.96^{b}	2.99^{a}	1.76^{a}	1.39^{a}	1.22^{a}	2.09^{ab}	1.69^{a}	1.54^{a}	2.09^{ab}	–	12.21^{c}	2.36^{ab}	0.419

All values are mean of 6 fish.
Values in the same row with the same superscripts are not significantly different ($P < 0.05$).
[a] 20:1 represents the sum of 20:1$n-9$ and 20:1$n-11$.
[b] Total FA (%) per g of lipid.

Table 8
Two way ANOVA for size and portion effects (and combination of both) on the fatty acid composition, index of atherogenicity and index of thrombogenicity

Fatty acid	Size		Portion		Size × portion	
	F value	P	F value	P	F value	P
14:0	133.92	***	37.71	***	3.09	***
16:0	14.70	***	17.25	***	0.66	ns
18:0	58.27	***	29.72	***	5.58	***
16:1$n-7$	138.54	***	37.35	***	5.69	ns
18:1$n-7$	11708.02	***	1.73	ns	0.48	***
18:1$n-9$	6843.80	***	25.59	***	7.31	ns
20:1[a]	74.44	***	5.19	***	1.46	***
18:2$n-6$	112.14	***	25.00	***	4.20	***
20:4$n-6$	27.95	***	37.94	***	5.43	***
18:3$n-3$	39.66	***	16.16	***	1.90	*
18:4$n-3$	26.16	***	27.73	***	3.13	***
20:5$n-3$	62.41	***	36.67	***	1.69	*
22:5$n-3$	19.42	***	21.20	***	2.51	***
22:6$n-3$	29.91	***	40.95	***	6.03	***
$\sum$ SFA	23.63	***	19.99	***	1.34	ns
$\sum$ MUFA	12.74	***	30.22	***	5.53	***
$\sum$ PUFA	25.86	***	27.43	***	5.08	***
$\sum$ HUFA	28.54	***	34.28	***	5.68	***
$\sum n-3$ PUFA	26.92	***	31.02	***	5.77	***
$\sum n-6$ PUFA	232.82	***	5.75	***	1.54	ns
$\sum n-3$ HUFA	29.28	***	33.32	***	5.61	***
$\sum n-6$ HUFA	27.95	***	37.94	***	5.43	***
$n-3/n-6$	83.25	***	26.10	***	4.97	***

P*** ⩽ 0.001, ** ⩽ 0.01, * ⩽ 0.05, ns – not significant.
[a] 20:1 represents the sum of 20:1$n-9$ and 20:1$n-11$.

Table 9
Statistical relationship and regression coefficients (R^2) of proximate parameters and major fatty acid classes (y) relative to the lipid content (x)

Parameter	Equation	R^2	P
Moisture[a]	$-0.839X+80.00$	0.971	<0.05
Protein[a]	$-0.147X+18.76$	0.560	<0.05
Ash[a]	$0.004X+1.15$	0.006	>0.05
Energy[b]	$0.3481X+4.54$	0.866	<0.05
SFA[a]	$0.0158X+31.78$	0.007	>0.05
MUFA[a]	$11.96+22.66\,(1-e^{-0.8664X})$	0.863	–
PUFA[a]	$16.28\,e^{-0.7056X}+33.82$	0.856	–
$n-3$ PUFA[a]	$21.50\,e^{-0.7962X}+24.20$	0.895	–
$n-6$ PUFA[a]	$10.14\,(1-e^{-1.699X})-0.5023$	0.429	–
EPA[a]	$-0.029X+7.564$	0.119	>0.05
DHA[a]	$22.564\,e^{-0.7971X}+9.486$	0.936	–
ArA[a]	$2.9991\,e^{-0.5922X}+0.9489$	0.892	–

[a] Value expressed in %.
[b] Value expressed in kJ g^{-1}.

point of view, fish are usually classified into groups according to their lipid content (Cowey, 1993; Haard, 1992): lean (<2%); low-fat (2–4%); medium-fat (4–8%) and high-fat (>8%). Murray cod (both wild and farmed) have previously been referred to as lean fish (De Silva et al., 2004). The present study shows that farmed Murray cod need to be re-classified and placed amongst those fish considered medium-fat to highly fat, and this, together with the knowledge of the abundant content of $n-3$ PUFA in its fillet, is an important positive characteristic which should attract the consumer's attention.

The saturated fatty acid content remained constant and did not vary much amongst the different fillet portions and/or the different fish sizes. This is in agreement with the observation of Turchini et al. (2003a,b) and Francis et al. (2006) in that SFA are not used efficiently by Murray cod as an energy source and are therefore accumulated at an optimal level compared to other fatty acid classes. On the contrary to SFA, there was a decrease in the PUFA content and an increase in that of MUFA in the muscle. This is expected as fatty acids are the primary constituents of polar and non polar lipids, specifically phospholipids and triacylglycerols, respectively. Triacylglycerols are depot fats while phospholipids are essential for membrane build up and fluidity (Sargent, Bell, McEvoy, Tocher, & Estevez, 1999). Phospholipids contain higher quantities of PUFA, and lower levels of monounsaturates compared to the non polar fraction (Henderson & Tocher, 1987).

Overall, in highly fat-rich fillet portions $n-3$ fatty acids were less abundant, whereas $n-6$ were predominant, suggesting that $n-6$ are preferentially deposited as "stored lipid", while $n-3$ fatty acid are important part of the "functional lipid". Surprisingly, the eicosapentaenoic acid content remained fairly uniform in the different fillet portions, suggesting that its percentage content is similar in both stored and functional lipids.

In fish, generally, accumulation of certain fatty acids in muscle tissue is dependent on their dietary concentration (Kirsch, Iverson, Bowen, Kerr, & Ackman, 1998; Nielsen et al., 2005; Olsen, Løvaas, & Lie, 1999; Shearer, 2001;). However, in this study, the $n-3/n-6$ ratio was higher in muscle than in the diet. The same trend has been observed in salmonids (Arzel et al., 1994; Suzuki, Okazaki, Hayakawa, Wada, & Tumara, 1986; Turchini et al., 2003b), suggesting that Murray cod tend to accumulate and store $n-3$ while using $n-6$ as an energy source.

Despite convincing evidence that EPA and DHA are beneficial to the human health, many developed countries still have a low intake of EPA and DHA. The average estimated daily intake of EPA + DHA was found to be 180 mg in Australia (Ollis et al., 1999) and 130 mg in the USA (Logan, 2004), which is well below the Adequate Daily Intake (ADI) of 650–900 mg for healthy adults (Simopoulos et al., 1999). Therefore, on average, a four-fold increase in fish consumption would be required to achieve the ADI.

Taking all these considerations into account, it is of paramount importance that nutritionists and fish consumers know the differences, if any, amongst fish portions (particularly in large sized fish which are sometime sold as portions). In this study, it was evident that some portions of the fillet were nutritionally more beneficial than others. In medium sized fish, that consumers are more likely to consume, the percentage of $n-3$ PUFA g $lipid^{-1}$ was highest in P1. However, taking into consideration the lipid distribution amongst the different portions of medium sized fish and the contribution that each portion gives to the total fillet in terms of flesh weight, P5 and P8 were the portions that provided the highest amount of EPA+DHA (189 and 186 mg or 23.3% and 23.0%, respectively).

Comparing the results obtained with the data provided by Fineli® (Fineli, 2005), it is interesting to notice that Murray cod ranks very well after eel, tuna, rainbow trout, Baltic herring, salmon and flounder for its EPA and DHA content, and contains more HUFA $n-3$ than white fish, vendace, bream, cod, perch and pike.

In conclusion, this study has shown that there are distinct differences in lipid and fatty acid distribution amongst different portions of the fillet of farmed Murray cod. These results should provide guidance to lipid researchers and sensorial food analysts in selecting representative fillet portions for their studies.

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