
RESEARCH NOTE

Chemical Composition of Light and Dark Muscle of Peruvian Anchovy (*Engraulis ringens*) and Its Seasonal Variation

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INTRODUCTION

The overall fish population, and particularly the pelagic species, has a high nutritional value due to their content of relevant molecules for human health such as essential amino acids, omega 3 fatty acids, and micronutrients (Huss, 1995).

About half of the world fish capture corresponds to pelagic species, which are used as fresh, canned, or cured products for human consumption. More recently, washed fish paste technologies such as “surimi” have been utilized as an alternative way of processing pelagic fish (Hultin and Kelleher, 2000).

The Peruvian anchovy (*Engraulis ringens*) is one of the pelagic species with greater biomass worldwide and has been reported as the most captured species by the marine fishing industry (Csirke, 2005). It is found mainly in the southeastern Pacific Ocean, its geographical distribution encompassing the Peruvian and Chilean littoral between 6° S and 42° 31' S (Food and Agriculture Organization of the United Nations [FAO], 1988). It has been traditionally used to make fish meal for animal consumption; nevertheless, in recent years it has also been incorporated in the human diet.

The muscle of the Peruvian anchovy is composed of dark and light muscle. While the light muscle is mainly involved in sudden movements (anaerobic) and occupies a large volume in the body, the dark muscle is located along the lateral line and is used for constant movements (aerobic). The proportion of dark muscle varies between 1 and 30% of total muscle according to the species and the life stage in the biological cycle (Bae et al., 2011). The species with a greater proportion of dark muscle have higher levels of lipids, myoglobin, alkali-soluble protein, stroma, and glycogen (Chaijan et al., 2004). Because of its higher concentrations of fat and metals, the dark muscle is more prone to lipid oxidation (Flick et al., 1992).

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The Peruvian anchovy spawns from August to March, with two intensity peaks: the major one occurs in the winter (August–September), and a second, less intense, in the summer (February–March; Bouchon et al., 2010). The reproductive potential is highly variable as a consequence of the diverse size composition of the population during the spawning season, which depends on the interaction between environmental and biological factors (Espinoza et al., 2009). Changes in the fat content of specimens are mainly determined by the reproductive stage, but also by nutritional and environmental conditions. The fat content reported for adult anchovy varies from 0.9 to 15% (Lam, 1968; Ayala et al., 2002).

In spite of *E. ringens* being the most captured species worldwide, little is known about the nutritional characteristics, in particular of its dark and light muscle. To gain insight into this matter, the chemical composition, fatty acid profile, and macro and micronutrient content were determined in both types of muscle from specimens captured in the Peruvian littoral in Winter 2010 and Fall 2011. The amino acid composition of whole lyophilized fillets is also reported.

MATERIALS AND METHODS

Fish samples were obtained from artisanal fishing vessels (capacity of 5 tonnes) in the Pisco area (13° 48' S) on August 11, 2010 (winter sample; size range: 9–17 cm; mode: 14 cm) and on April 1, 2011 (fall sample; size range: 7–17 cm; mode: 14.5 cm). One hundred kilograms of fresh fish were placed in a mix of water and ice (< 2°C) and brought to the Instituto Tecnológico Pesquero (ITP) no later than 12 h after the capture. Fifty specimens with sizes between 13 and 15 cm were selected for carrying out the analyses. In order to facilitate the separation of dark and light muscle, the samples were frozen at –20°C. Both types of muscle were later lyophilized and stored at room temperature until analysis.

Proximate composition was determined following FAO (1986) methods in whole fresh fillets, as well as lyophilized samples of light and dark muscle. Amino acids were identified and quantified in whole lyophilized fillets by high performance liquid chromatography (HPLC) as described by Heinrikson and Meredith (1984). The remaining analyses were carried out only in lyophilized light and dark muscle: Fatty acid profile was obtained by gas chromatography in a capillary column (Prevot and Mordret, 1976) after fat extraction (Bligh and Dyer, 1959); micronutrient content was measured by atomic absorption spectrophotometry in ashes dissolved in 0.1 N HCl (975.03 method; AOAC, 2005); phosphorus was determined using a colorimetric assay (965.17 method; AOAC, 2005). The eicosapentanoic acid (EPA) and docosahexanoic acid (DHA) content of lyophilized light and dark muscle was estimated from their percentages in the fatty acid profile and the corresponding crude fat content by applying the formula:

$$\text{Fatty acid (g/100 g)} = \text{crude fat (g/100 g)} \times \text{proportion of fatty acid (\%)} \times \text{CF},$$

where CF is a conversion factor with a value of 0.9 for dark muscle and 0.7 for light muscle (Greenfield and Southgate, 2003).

Proximate analyses and macro and micronutrient determinations were performed in triplicate; the fatty acid profile and amino acid composition were determined in duplicate.

A Student's *t*-test was used to compare means from proximate analysis data of whole fillets, and a one-way analysis of variance (ANOVA) was used to find differences in mineral and proximate composition between dark and light muscle. Post hoc analysis was carried out with the Tukey's test. A *p*-value < 0.05 was considered significant. Analyses were performed using SPSS-10 (SPSS, Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

A significant variation in moisture, fat, and protein content ($p < 0.05$) was found between whole fresh fillets from fish captured in Winter 2010 and Fall 2011, presumably related to the spawning activity (Table 1). As expected, the specimens caught in the winter—intense spawning season—showed a lower fat content than those caught in the fall; this finding may reflect a fat accumulation by the latter after leaving the second—less intense—spawning peak. These results are in agreement with an earlier report (Alheit et al., 1984). If the proximate composition is expressed on a dry weight basis, the differences in the protein content become more evident (Table 1). Winter specimens with low fat content have significantly higher levels of protein.

While light muscle showed fairly constant values of fat and protein on a dry weight basis in both seasons, the dark muscle was much more variable (Table 1). The main source of this variation might be the nonpolar lipid fraction (triglycerides), as reported for sardines' dark muscle (Pazos et al., 1984; Pacheco-Aguilar et al., 2000).

The fatty acid profile of the light muscle revealed that EPA and DHA were among the three more abundant fatty acids in both winter and fall samples (Table 2), thus confirming that this type of muscle has a higher proportion of polyunsaturated n-3 fatty acids (about 50%) and therefore polar lipids, compared with the dark muscle. However, when estimating the absolute content of EPA and DHA, the dark muscle shows greater levels (Table 2), most likely because its high fat content overcompensates the lower proportions of these fatty acids.

The fish dark muscle contains cofactors associated with enzymes involved in the oxygen-dependent generation of metabolic energy (Kisia, 1996). The micronutrient analyses carried out in this study revealed that the dark muscle of *E. ringens* bears 10- and 20-fold higher levels of copper and iron, respectively, than the light muscle (Table 3), regardless of the season of capture. This finding is consistent with the role of dark muscle in fish cruising.

On the other hand, potassium and magnesium contents were higher in the light muscle, whereas sodium and phosphorus showed similar levels in both types of muscle. As for the higher content of calcium found in the light muscle, it is most likely a measurement artifact due to the presence of small thorns that could not be removed from the samples.

Finally, all the essential amino acids required in the human diet were present in the whole lyophilized fillet as shown in Table 4. The amino acid content was similar to that reported for anchovy meal and other fish meals, with the sole exception of arginine, which was more abundant in the whole lyophilized fillet (Table 4).

TABLE 1
Proximate composition (%) of whole fresh fillets and lyophilized light and dark muscle of Peruvian anchovy in Winter 2010 and Fall 2011

	Whole fresh fillets		Light muscle		Dark muscle	
	Winter 2010	Fall 2011	Winter 2010	Fall 2011	Winter 2010	Fall 2011
Moisture	76.48 ± 0.16 ^a	72.18 ± 0.08 ^b	—	—	—	—
Ash	1.92 ± 0.08 ^a	1.96 ± 0.09 ^a	7.47 ± 0.79 ^a	6.94 ± 0.40 ^{a, b}	5.12 ± 1.02 ^{a, b}	6.02 ± 0.37 ^b
Crude fat	1.52 ± 0.09 ^a	7.73 ± 0.08 ^b	2.76 ± 0.18 ^a	2.66 ± 0.26 ^a	12.35 ± 0.51 ^b	18.16 ± 0.29 ^c
Protein	19.86 ± 0.12 ^a	18.10 ± 0.07 ^b	89.48 ± 0.31 ^a	89.42 ± 0.38 ^a	82.25 ± 0.24 ^b	75.56 ± 0.20 ^c

In whole fresh fillets, means with different superscript letters within rows are significantly different ($p < 0.05$). In light and dark muscle, means with different superscript letters within rows are significantly different ($p < 0.05$).

TABLE 2
Fatty acid profile (%) and EPA and DHA content (g/100 g dry weight) of lyophilized light and dark muscle of Peruvian anchovy in Winter 2010 and Fall 2011

Fatty acids (%)		Winter 2010		Fall 2011	
		Light	Dark	Light	Dark
14:0	Miristic acid	3.4	7.6	6.0	7.4
15:0	Pentadecanoic acid	0.3	0.5	0.5	0.5
16:0	Palmitic acid	22.7	30.9	23.0	21.1
16:1	Palmitoleic acid	3.2	8.4	6.2	8.7
18:0	Stearic acid	3.6	7.0	3.1	4.2
18:1 n-9	Oleic acid	5.1	11.4	5.5	7.0
18:1 n-7	Vaccenic acid	3.4	6.4	3.0	3.4
18:2 n-6	Linoleic acid	0.5	0.8	0.8	1.0
18:4 n-3	Estearidonic acid	1.1	0.9	1.4	1.6
20:1 n-9	Eicosenoic acid	0.3	0.6	0.3	0.6
20:3 n-3	Eicosatrienoic acid	1.8	0.8	2.1	2.0
20:5 n-3	Eicosapentaenoic acid (EPA)	14.7	8.9	15.1	13.9
22:5 n-3	Clupadonic acid	2.5	1.7	2.3	2.6
22:6 n-3	Docosahexaenoic acid (DHA)	35.6	13.0	27.0	18.7
EPA (g/100 g lyophilized)		0.28	0.99	0.28	2.25
DHA		0.69	1.44	0.50	3.05

TABLE 3
Mineral content* of lyophilized light and dark muscle of Peruvian anchovy in Winter 2010 and Fall 2011

	Winter 2010		Fall 2011	
	Light	Dark	Light	Dark
Fe (ppm)	9.3 ± 7.2 ^a	255.2 ± 2.3 ^b	12.6 ± 3.7 ^a	280.8 ± 8.7 ^b
Cu (ppm)	1.6 ± 0.4 ^a	20.9 ± 1.2 ^b	1.9 ± 0.2 ^a	19.4 ± 1.5 ^b
Na (mg/100 g)	532.9 ± 130.0 ^a	638.7 ± 115.0 ^a	527.5 ± 110.0 ^a	641.2 ± 104.0 ^a
K (mg/100 g)	2769.0 ± 34.0 ^a	1597.0 ± 13.0 ^b	2769.0 ± 33.0 ^a	1597.0 ± 13.0 ^b
Mg (mg/100 g)	175.3 ± 27.0 ^a	128.0 ± 12.0 ^b	183.2 ± 20.0 ^a	130.1 ± 11.0 ^b
Ca (mg/100 g)	197.0 ± 7.8 ^a	70.0 ± 6.7 ^b	190.9 ± 29.0 ^a	66.4 ± 6.3 ^b
P (mg/100 g)	1516.6 ± 376.0 ^a	1875.3 ± 329.0 ^a	1967.5 ± 213.0 ^a	1940.5 ± 343.0 ^a

*Significant differences are indicated with superscript letters.

The present study provides novel data on the chemical characteristics of dark and light muscle of the Peruvian anchovy in two different seasons. This information shall contribute to a better use and management of the resource.

ACKNOWLEDGMENTS

The authors thank Dr. Daniel Clark for assistance with the manuscript.

TABLE 4
Amino acid composition (g/100 g) of whole lyophilized fillets of Peruvian anchovy and fish meals*

Amino acids	Peruvian anchovy	Anchovy meal	White fish meal	Menhaden meal	Herring meal
Trp	0.75	0.78	0.67	0.49	0.83
His	1.12	1.59	1.34	1.42	1.74
Thr	3.04	2.82	2.57	2.46	3.07
Val	3.39	3.46	3.02	2.77	3.90
Met	2.12	1.95	1.68	1.63	2.16
Ile	3.24	3.06	2.72	2.28	3.23
Leu	5.85	4.98	4.36	4.16	5.46
Phe	3.38	2.75	2.28	2.21	2.82
Lys	6.17	5.07	4.53	4.51	5.47
Arg	8.04	3.81	4.02	3.68	4.21
Asp	6.89	—	—	—	—
Glu	12.3	—	—	—	—
Ser	2.78	—	—	—	—
Gly	3.05	3.68	4.42	4.46	4.30
Ala	1.99	—	—	—	—
Pro	2.75	—	—	—	—
Tyr	2.14	2.22	1.83	1.80	2.25
Cys	—	0.65	0.75	0.57	0.72
Protein (%)	74.3	65.00	62.20	61.30	72.00

“—” Not determined.

*Source: FAO Feedpedia—Animal Feed Resources Information System
(<http://www.fao.org/ag/aga/agap/frg/afris/default.htm>).

FUNDING

This study was supported by the Production Technological Institute (Instituto Tecnológico Pesquero del Perú).

REFERENCES

- Alheit, J., Alarcón, H., and Macewics, C. 1984. Spawning frequency and sex ratio in Peruvian anchovy. *CalCOFI Rep.* 25: 43–52.
- AOAC. 2005. *Official Methods of Analysis of the Association of Official Analytical Chemists* (18th ed.). Gaithersburg, MD: AOAC.
- Ayala, M. E., Albrecht-Ruiz, M., Salas, A., and Paredes, J. 2002. Fat content of Peruvian anchovy (*Engraulis ringens*), after “El Niño” phenomenon (1998–1999). *J. Food Comp. Anal.* 15: 627–631.
- Bae, J., Hwang, S., Yoon, S., Noh, I., and Lim Y. 2011. Comparison between ordinary and dark muscle extracts of yellow-tail (*Serila quinqueradiata*) on chemical characteristics, antiproliferative and antioxidant properties. *J. Food Tech.* 9(3): 99–105.
- Bligh, E., and Dyer, W. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37: 911–917.
- Bouchon, M., Ayón, P., Mori, J., Peña, C., Espinoza, P., and Hutchings, L. 2010. Biology of Peruvian anchovy (*Engraulis ringens* Jenyns). *Bol. Inst. Mar. Perú* 25(1–2): 23–30.
- Chaijan, M., Benjakul, S., Visessanguan, W., and Faustman, C. 2004. Characteristics and gel properties of muscles from sardine (*Sardinella gibbosa*) and mackerel (*Rastreliger kanagurta*) caught in Thailand. *Food Res. Int.* 37(10): 1021–1030.
- Csirke, J. 2005. Global production and state of marine fishery resources. In: *Review of the State of World Marine Fishery Resources* (FAO Fisheries Technical Paper 457). Rome, Italy: FAO.

- Espinoza, C., Vera, V., Perea, A., Buitrón, B., Rojas, P., and Kjesbu, O. 2009. Effect of feeding ration on gonad maturation and fat accumulation in Peruvian anchovy (*Engraulis ringens Jenyns*, 1842) in captivity. *Lat. Am. J. Aquat. Res.* 37(2): 181–190.
- FAO. 1986. *Manuals of Food Quality Control—7. Food Analysis: General Techniques, Additives, Contaminants and Composition* (FAO Food and Nutrition Paper T14/7). Rome, Italy: FAO with the support of the Swedish International Development Authority (SIDA).
- FAO. 1988. *FAO Species Catalogue—Clupeoid Fishes of the World (Suborder Clupeoidei): An Annotated and Illustrated Catalogue of the Herrings, Sardines, Pilchards, Sprats, Shads, Anchovies, and Wolf-Herrings.* (FAO Fisheries Synopsis, No. 125, Vol. 7). Rome, Italy: FAO.
- Flick, G., Hong, G., and Knobl, G. 1992. Lipid oxidation of seafood during storage. In: *Lipid Oxidation in Food* (ACS Symposium Series, Vol. 500). St. Angelo, A. J. (Ed.). Washington, DC: American Chemical Society. Pp. 183–207.
- Greenfield, H., and Southgate, D. A. T. 2003. *Food Composition Data: Production, Management and Use* (2nd ed.). Rome, Italy: FAO.
- Heinrikson, R., and Meredith, S. 1984. Amino acid analysis by reverse-phase high-performance liquid chromatography: Precolumn derivatization with phenylisothiocyanate. *Anal. Biochem.* 136(1): 65–74.
- Hultin, H., and Kelleher, S. 2000. Surimi processing from dark muscle fish. In: *Surimi and Surimi Seafood*. Park, J. W. (Ed.). New York, NY: Marcel Dekker. Pp. 59–77.
- Huss, H. H. (Ed.). 1995. *Quality and Quality Changes in Fresh Fish* (FAO Fisheries Technical Paper 348). Rome, Italy: FAO.
- Kisia, S. M. 1996. Structure of fish locomotory muscle. In: *Fish Morphology: Horizon of New Research*. Datta Munshi, J. S., and Dutta, H. M (Eds.). Brookfield, VT: A.A. Balkema Publishers. Pp. 169–178.
- Lam, R. C. 1968. Fat Content Variation in Peruvian Anchovy (*Engraulis ringens*), (IMARPE Informe No. 24). Callao, Peru: Instituto del Mar del Perú.
- Pacheco-Aguilar, R., Lugo-Sánchez, M., and Robles, M. 2000. Postmortem biochemical and functional characteristic of Monterey sardine muscle stored at 0°C. *J. Food Sci.* 65(1): 40–47.
- Pazos, M., Vicetti, R., and Wakao, A. 1984. Fatty acids composition of sardine (*Sardinops sagax sagax*). *Bol. Inv. Inst. Tec. Pes.* 2(1): 1–24.
- Prevot, G., and Mordret, M. 1976. Utilisation des colonnes capillaires pour l'analyse des corps gras par chromatographie en phase gazeuse. *Rev. Franc. Corps Gras.* 23: 7–8.

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