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CARACTERÍSTICAS MORFOMÉTRICAS, MERÍSTICAS, DE LA CANAL Y DE LA CARNE DE ESPECIES DE PEZ NATIVAS DE AGUA DULCE DE ECUADOR.

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CÓRDOBA, 2017

TITULO: *Características morfométricas, merísticas, de la canal y de la carne de especies de pez nativas de agua dulce de Ecuador*

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POSTGRADO EN RECURSOS NATURALES Y GESTIÓN SOSTENIBLE

Características morfométricas, merísticas, de la canal y de la carne de especies de pez nativas de agua dulce de Ecuador

Tesis presentada por D. MARTIN ARMANDO GONZÁLEZ VÉLEZ
para optar al grado de Doctor por la Universidad de Córdoba
(España)

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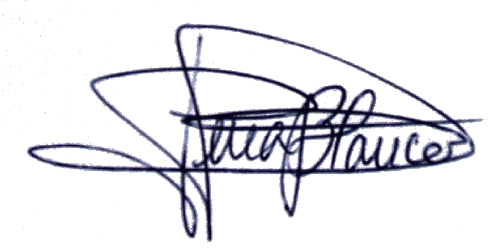
INFORMA:

Que la tesis doctoral titulada “Características morfométricas, merísticas, de la canal y de la carne de especies de pez nativas de agua dulce de Ecuador.”, que se recoge en la siguiente memoria y de la que es autor MARTIN ARMANDO GONZALEZ VELEZ, ha sido realizada bajo mi dirección, cumpliendo las condiciones exigidas para que la misma pueda optar al Grado de Doctor por la Universidad de Córdoba.

Lo que suscribo como director de dicho trabajo y a los efectos oportunos, en Córdoba a uno de junio de dos mil diecisiete.



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TÍTULO DE LA TESIS:

CARACTERÍSTICAS MORFOMÉTRICAS, MERÍSTICAS, DE LA CANAL Y DE LA CARNE DE ESPECIES DE PEZ NATIVAS DE AGUA DULCE DE ECUADOR.

DOCTORANDO: **D. MARTIN ARMANDO GONZÁLEZ VÉLEZ**

INFORME RAZONADO DEL/DE LOS DIRECTOR/ES DE LA TESIS

(Se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

Durante el desarrollo de la Tesis el doctorando ha profundizado en el conocimiento de las principales características morfométricas, merísticas y calidad de la canal y de la carne de especies de peces nativas de Ecuador, conocimientos que son extrapolables al resto de poblaciones de especies de peces nativos ecuatorianos. Asimismo, el doctorando ha adquirido las habilidades y competencias necesarias para poder abordar la problemática del sector desde una doble perspectiva; por una parte, desde la orientación investigadora con toda su secuencia metodológica y por otra parte la resolución de problemas sectoriales de modo solvente.

La Tesis plantea como objetivo estratégico el conocimiento del rango biológico de variación de los peces cultivados y silvestres, así como su composición nutricional como punto de partida del programa de desarrollo piscícola que permita la mejora de las producciones en el sistema bajo criterios de sostenibilidad. Se aplica una metodología actual sobre la caracterización morfométrica, merística y calidad de la carne en una población no descrita científicamente hasta ahora. Las especies estudiadas (Cichalosoma festae y Aequidens rivulatus) tienen gran importancia comercial para la población de Ecuador, por lo que la información obtenida será incluida en los registros de la

composición nutricional de los peces de agua dulce de Ecuador. La presente tesis doctoral marca el final la primera fase de un proyecto de desarrollo acuícola que precisa continuar con investigaciones complementarias en el resto de peces de agua dulce de interés zootécnico del Ecuador.

La presente Tesis Doctoral ha dado lugar a los siguientes trabajos:

Trabajos de investigación:

González, M.A., J. M. Rodríguez, E. Angón, A. Martínez, A. García, and F. Peña. (2016). Characterization of morphological and meristic traits and their variations between two different populations (wild and cultured) of *Cichlasoma festae*, a species native to tropical Ecuadorian rivers. *Archives Animal Breeding,* 59, 435–444.

González, M.A., Angón, E., Rodriguez, J., Moya, A., García, A. and Peña, F. (2017). Yield, flesh parameters, and proximate and fatty acid composition in muscle tissue of wild and cultured Vieja Colorada (*Cichlasoma festae*) in tropical Ecuadorian river. *Spanish Journal of Agricultural Research. In press.*

Rodríguez, J., Angón, E., **González, M.,** Perea, J., Barba, C., García, A. (2017). Allometric relationship and growth models of juveniles of *Cichlasoma festae* (Perciforme: Cichlidae), a freshwater species native in Ecuador*. Revista de Biología Tropical, 65 (3).* http://dx.doi.org/10.15517/rbt.v65i3.26173

González, M. A., E. Angón, J. M. Rodríguez, A. García, F. Peña. (2017). Meristics and morphometrics characters, traditional and truss network measurements, for the characterization and differentiation of two populations, wild and cultured, of Vieja Azul (*Aequidens rivulatus*) from the rivers of the Province of Los Rios, (Ecuador). (En revision).

Rodríguez, J., Moya, A., Duart, P., **González, M.,** Gallegos, M., Merizalde, D. García, A. (2014). Aplicación de la colorimetría como instrumento de valoración de los recursos acuícolas nativos en Ecuador: Vieja Colorada (*Cichlasoma festae*) y la Vieja azul (*Andinoacara rivulatus*). Revista Científica de la Universidad Estatal de Quevedo. 7(2): 13-27.

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Trabajos fin master:

González, M.A., Peláe, F., Martínez, A., Avilés, C., Francisco Peña., (2016). The "Criollo Negro de la Costa Ecuatoriana" pigs: effect of sex and rearing system on performance, carcass and meat. *Spanish Journal of Agricultural Research*,14 (1), e0601. http://dx.doi.org/10.5424/sjar/2016141-7681

Capítulo de libro:

Rodríguez, J., **González, M.,** Moya, A., Angón, E., García, A. (2015). Perspectivas de la Piscicultura en La Provincia de Los Ríos. Ecuador. En Murillo G, García A, Lara M, Plaza L, Rodríguez D. Gestión Sustentable de Empresas Agroalimentarias. Editado por la Universidad Técnica Estatal de Quevedo (UTEQ). Ecuador. 5: 371-384.

Trabajos presentados a congresos:

González M.A.; Rodríguez J.; Angón E; García A.; Peña F; Moya L.A., Gallegos M.Z. (2015). Características físico-químicas y rendimientos de vieja colorada (*Cichlasoma festae*) criada en dos sistemas de producción: silvestre y cautividad. Libro de Proceedings III Congreso Internacional de Ciencia Tecnología, Innovación y Emprendimiento Universidad Estatal de Bolívar, Ecuador, 203-208.

González M.A.; Rodríguez J.; Moya L.A., Duarte P. Gallegos M.Z. Merizalde D. González A. (2014). Revisión de la calidad de peces continentales. Proceedings del IV Simposium Latinoamericano de Producción Animal ALPA-ECUADOR. 63-64.

Rodríguez, J.; Moya, A.; Angón, E.; Torres, Y.; **González, M.;** Perea, J.; García, A.; (2015). Relación entre las medidas exteriorista del Cichlasoma festae en edad juvenil en condiciones experimentales semicontroladas. XI Congreso de la Federación Iberoamérica de Razas Criollas y Autóctonas. Zaragoza. España. 12, 214-216.

Rodríguez, J., Moya, A., Angón, E., Medina, M., **González, M**., Perea, J., García, A. (2015). Patrones de crecimiento del Cichlasoma festae en edad juvenil en

condiciones experimentales semicontroladas. XI Congreso de la Federación Iberoamérica de Razas Criollas y Autóctonas. Zaragoza. España. 12, 217-220.

Rodríguez, J., Vivas, R., Medina, M., **González, M**., Barrera, A., García, A. (2015). Parámetros ambientales para la reproducción natural de la vieja colorada Cichlasoma festae en confinamiento. XXIV Congreso de la Asociación Latinoamericana de Producción Animal y XL Congreso de la Sociedad Chilena de Producción Animal. Puerto Varas. Chile. 149 pp.

González, M., Angón, E., Rodríguez, J.; López, M., Moya, A., Peña, F. (2017). Calidad de la canal y la carne del Guachinche (*Hoplias microlepis*) criado de forma silvestre. IV Congreso Internacional de Ciencia Tecnología, Innovación y Emprendimiento. Universidad Estatal de Bolívar. Ecuador.

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2017. Departamento de Producción Animal de la Universidad de Córdoba, España. Durante el período comprendido entre el 10 de abril al 10 de mayo.

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2.- "Crecimiento de peces continentales nativos y exóticos en el sistema biofloc. Efecto del biofloc en el crecimiento". Financiado por el FOCICYT de la Universidad Técnica Estatal de Quevedo (Ecuador) y dirigido por D. Jorge Magno Rodríguez Tobar y D. Antón Rafael García Martínez.

3.- "Cultivo de peces continentales nativos y tilapia, en estanques de geomembrana, para mejorar la alimentación de la población de la zona rural". Financiado por el FOCICYT de la Universidad Técnica Estatal de Quevedo (Ecuador) y el Gobierno Autónomo Descentralizado de Mocache y dirigido por D. Jorge Magno Rodríguez Tobar y D. Antón Rafael García Martínez.

4.- "Captura, reproducción y conservación de reproductores de Vieja colorada (Cichlasoma festae) de las represas: Daule–Peripa, La Esperanza, y Pilahuin". Financiado por el FOCICYT de la Universidad Técnica Estatal de Quevedo

(Ecuador) y dirigido por D. Jorge Magno Rodríguez Tobar y D. Antón Rafael García Martínez.

Trabajos dirigidos en Pregrado:

2015. Características fisico-químicas de la carne de vieja colorada (Cichlasoma festae).

2015. Características físico-químicas de la carne de vieja azul (Aequidens rivulatus).

2015. Características físico – químicas del bocachico (Ichthyoelephas humeralis)

2016. Características morfométricas físico-químicas del guanchiche (*Hoplias* spp) en Los Ríos, Quevedo, Babahoyo y la represa Daule Peripa situados en la costa

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, a 1 de junio de 2017

Fdo.: Francisco Peña Blanco

Fdo.: Elena Angón Sánchez de Pedro

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La Universidad de Córdoba (España) y la Universidad Técnica Estatal de Quevedo (Ecuador).

Asimismo, el estudio se ha desarrollado dentro del marco de los Proyecto de investigación:

1.- “Caracterización del crecimiento y efecto de la densidad de las especies nativas *Cichlasoma festae* (Vieja Colorada) y *Aequidens rivulatus* (Vieja Azul)”. Financiado por el FOCICYT de la Universidad Técnica Estatal de Quevedo (Ecuador) y dirigido por D. Jorge Magno Rodríguez Tobar y D. Antón Rafael García Martínez.

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Capítulo I

1. INTRODUCCION

INTRODUCCIÓN

1. Justificación

La producción de pescado en el mundo se estima en 164 millones de toneladas en el 2020, con un crecimiento de alrededor del 15% por encima del nivel medio en el período 2008-2010 (FAO 2011). Presenta un crecimiento constante en las últimas cinco décadas, con un aumento anual medio del 3.2 por ciento, superando el crecimiento de la población mundial en 1.6 por ciento. El consumo per cápita mundial de pescado se cifró en 9.9 kg en la década de 1960, aumentando a 19.2 kg en el año 2012 (FAO 2014).

El pescado es una de las fuentes de proteína animal más importante, e imprescindible para una dieta saludable. Contiene importantes cantidades de aminoácidos, ácidos grasos insaturados, vitaminas y minerales que contribuyen al desarrollo y mantenimiento del organismo. Por su constitución física y química, la carne de pescado presenta una digestión acelerada en el tracto digestivo del consumidor (Turan *et al.*, 2006; Oğuzhan *et al.*, 2009; Kızılaslan & Nalıncı, 2013). Por su valor nutritivo es considerado un alimento funcional, que ayuda a prevenir enfermedades tales como presión arterial, colesterol, enfermedad de Alzheimer y diversos tipos de cáncer (Verbeke y Vackier, 2005; Turan *et al.*, 2006; McNaughton *et al.*, 2008, Pieniak *et al.*, 2008).

La carne de pescado desempeña un papel fundamental en una dieta nutritiva y equilibrada y su consumo se asocia con varios beneficios para la salud. De hecho, estos productos proporcionan un número de nutrientes, incluyendo proteínas, ácidos grasos omega-3 poliinsaturados de cadena larga tales como ácidos eicosapentaenoico y docosahexaenoico, y un número elevado de vitaminas y minerales (Weichselbaum *et al.*, 2013).

El pescado es uno de los productos alimenticios más ampliamente distribuido en el mundo y contribuye con el 6% de la proteína total suministrada en la

alimentación humana y aporta aproximadamente en el 24% de la proteína animal total prevista para la elaboración de harina de pescado para alimentar animales (Shilo y Sarig, 1989).

Los peces tienen mayor proporción de tejido muscular en relación a otros vertebrados por lo que se obtiene mayor rendimiento en ellos. Los principales músculos de los peces se encuentran en el tronco y la cola. La musculatura esquelética se encuentra formada por cortas unidades (Dragonetti, 2008).

La trazabilidad de la carne de pescado tiene mucha importancia sobre la calidad de la misma. En los países desarrollados, el pescado se mantiene en la cadena de frío desde su captura hasta el consumidor, manteniéndose buenas prácticas de manipulación en todo el proceso, lo que en definitiva ayuda a su conservación y calidad. Sin embargo, en países como Ecuador, donde se da poca importancia a la calidad, los peces no se someten a sistemas de procesamiento y se ofrecen en el mercado en forma fresca sin eviscerar y sin ningún sistema de refrigeración, y sin producir ningún valor agregado al producto.

Figura 1. 1 Conservación adecuada del pescado

Figura 1. 2 Conservación inadecuada de los especímenes

En cierta forma la abundancia del producto en la naturaleza y el sistema cotidiano de consumo en fresco, minimiza la percepción de la calidad de la carne de pescado. Sin embargo, diversas causas, entre las que se encuentran la sobre-explotación de los acuíferos y la degradación del medio natural, están reduciendo el número de capturas, en contraposición del aumento de la demanda. Por ello, la acuicultura está tomando el relevo y su importancia crece día a día por todo el mundo (Ajah *et al.*, 2006). La domesticación de diversos peces, estimados por la calidad de su carne, se hace necesaria para obtener una producción eficiente y sostenible desde el punto de vista social y medio-ambiental. En los últimos años, en las zonas costeras y de interior de Ecuador se han establecido familias y pequeñas empresas dedicadas a la producción en cautividad de diferentes especies de peces a fin de cubrir la demanda local de estos productos.

América latina cuenta con numerosas especies nativas con potencial en acuicultura. Entre ellas, por su diversidad y calidad de su carne, destaca la familia *Cichlidae*. Esta familia es la no-*Ostariophysan* más abundante en especies de agua dulce de todo el mundo. En conjunto presenta

aproximadamente 1900 especies (Kullander, 1998), de las que unas 402 se encuentran en América del norte, central y sur (Sparks y Smith, 2004). La mayoría de los cíclidos neotropicales ocupan hábitats en lagos, ríos y arroyos de corrientes lentas. La forma de su cuerpo es bastante variable, sobre todo moderadamente profunda y comprimida. La mayoría de los taxones están en el intervalo 10-20 cm, aunque las longitudes varían de aproximadamente 25-30 mm de tamaño adulto en *Apistogramma* y *Taeniacara*, a aproximadamente 1 metro en *Cichla temensis*.

En la provincia de Los Ríos, Ecuador, encontramos hábitats adecuados a este tipo de peces. Tradicionalmente, pescadores artesanales vienen realizando capturas en ríos, lagos, estanques, lagunas, barrancos y presas. Esta actividad se realiza a lo largo del año en áreas de ríos (Muñoz *et al.*, 2014) o entre mayo y enero en otras zonas del interior. Entre las especies más destacadas se encuentran el *Cichlasoma festae* y el *Andinoacara rivulatus (Aequidens rivulatus).* El *Cichlasoma festae*, es un pez teleósteo (Luna-Figueroa, 2000) de agua dulce (Boulenger, 1899) nativo de América del Sur continental, con una alta presencia en Ecuador. Es una de las nueve especies comercialmente importantes que habitan las aguas continentales de Ecuador, Colombia y Perú (Revelo y Elías, 2004). Se puede encontrar en ríos, lagos, estanques y presas (Pacheco y Chicaiza, 2008) y destaca por el color blanco de su carne, excelente gusto y alta aceptación en la cocina local (Barnhill *et al.*, 1974).

La Vieja Colorada se encuentra en la zona continental tropical de Colombia, Ecuador y Brasil (Crow, 1987). Por su parte, Barnhill et al (1973), estudiando la biología de los peces del rio Vinces en Ecuador la ha encontrado en todos los espejos de aguas cálidas.

El *Andinoacara rivulatus (Aequidens rivulatus)* es un colorido pez de agua dulce de la familia de los cíclidos. El pez es originario de los ríos de la cuenca del Pacífico de América del Sur, y se encuentra en las aguas costeras desde el Río Tumbes en Perú hasta el Río Esmeraldas en Ecuador (Belelli, 2002). La variedad “goldsaum” se encuentra desde el río Esmeralda y todo el sistema del río Guayas en Ecuador. En Perú se encuentra desde los ríos Tumbes, Zarumilla hasta el río Piura (Belelli, 2002). La variedad “silversaum” se distribuye sólo en Perú, desde el río Piura hasta el río Pisco, con pequeñas

variaciones entre la variedad norteña (Belelli, 2002). Los machos y hembras pueden alcanzar longitudes de 30 cm. En la naturaleza, el *A. rivulatus* vive en un clima tropical y prefiere el agua con un pH 6.5-8.0, una dureza del agua de 25.0 dGH y un rango de temperatura de 20-24 °C.

Con el fin de producir y preservar estas especies nativas, la administración estatal creó la Estación Experimental Cachari, ubicada en Babahoyo, en la provincia de Los Ríos, donde actualmente se está desarrollando un programa de conservación de especies nativas por la Subsecretaría de Acuacultura del Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (MAGAP). En esta estación experimental, se producen alevines para su distribución a acuicultores y para repoblar los ríos.

En los peces, la plasticidad fenotípica es muy elevada, presentando mayor variabilidad en caracteres morfológicos entre y dentro de poblaciones que en otros vertebrados. Las variaciones encontradas en caracteres morfológicos y merísticos es atribuida en parte a la influencia de parámetros medio-ambientales (Wimberger, 1992). Los peces son muy sensibles a cambios ambientales y rápidamente adaptan su morfología (Cabral *et al.*, 2003; Hossain *et al.*, 2010). Esta variación morfológica ha sido utilizada para el estudio de los cambios acaecidos a corto plazo como consecuencia del efecto de cambios en las condiciones del hábitat (Pinheiro *et al.*, 2005). Estas variaciones son diferentes según las especies. Finalmente, es importante para el acuicultor conocer estas variaciones, entre animales salvajes y cultivados de la misma especie, a fin de mejorar los resultados en cría en cautividad (Orban *et al.*, 2003).

Por todo ello, nos planteamos el estudio de las características morfológicas y merísticas de ejemplares las dos especies anteriormente reseñadas, criados en su hábitat natural y en piscifactoría, así como los rendimientos productivos y caracteres de importancia en la calidad de su carne.

2. Objetivos

El objetivo general es el análisis de las características morfométricas, merísticas, de la canal y de la carne de ejemplares de dos especies de pez nativas de agua dulce del Ecuador, Género Cichlasoma, procedentes de dos medios (silvestre y cultivado).

La consecución de este objetivo viene secuenciada por los siguientes objetivos parciales:

1. Caracterización de rasgos morfológicos y merísticos y sus variaciones entre dos poblaciones diferentes (silvestres y cultivadas) de *Cichlasoma festae* y *Andinoacara rivulatus (Aequidens rivulatus)* capturados en la provincia Los Ríos (Ecuador).
2. Rendimientos productivos, parámetros de calidad de la carne, composición proximal y de ácidos grasos en el tejido muscular de *Cichlasoma festae* y *Andinoacara rivulatus (Aequidens rivulatus)* capturados en diferentes medios (cultivados y silvestres) de la provincia de Los Ríos (Ecuador).

2. REVISIÓN BIBLIOGRAFICA

2.1. PECES

Los peces se definen generalmente como vertebrados acuáticos que usan branquias para obtener oxígeno del agua y cuentan con aletas caudales, pectorales, anales dorsales y pélvicas con sus respectivas espinas (Thurman y Webber, 1984). Además, son los vertebrados más numerosos, con alrededor de 20000 especies conocidas, de las cuales más del 58% son de aguas marinas. Son más comunes en las aguas cálidas y templadas de las plataformas continentales (unas 8000 especies). En las aguas polares frías se encuentran alrededor de 1000 especies. En el ambiente pelágico oceánico, lejos del efecto de la tierra, solo hay unas 225 especies. Sorprendentemente, en la zona mesopelágica más profunda del ambiente pelágico (entre 100 y 1000 m de profundidad) aumenta el número de especies. Existen alrededor de 1000 especies de los llamados peces de aguas medias (Thurman y Webber, 1984).

Como el resto de vertebrados, los peces tienen una columna vertebral y un cráneo que cubre el cerebro. La columna vertebral se extiende desde la cabeza a la aleta caudal y se compone de segmentos (vértebras). Estas vértebras se extienden dorsalmente para formar espinas neurales y en la región del tronco tienen procesos laterales que llevan costillas. Las costillas son estructuras cartilaginosas u óseas en el tejido conectivo (myocommata) entre los segmentos musculares (myotomos). Por lo general, también hay un número variable de costillas falsas que se extienden más o menos horizontalmente en el tejido muscular (Thurman y Webber, 1984).

Según el Codex Alimentarius, los peces son vertebrados acuáticos de sangre fría. Bajo esta denominación se incluyen píscidos, elasmobranquios y ciclóstomos (Dragonetti, 2008). Según la Norma Mercosur (Gmc/Res. Nº 40/94), se entiende como pescado al producto obtenido de animales acuáticos de sangre fría. Se excluyen los mamíferos acuáticos, los animales invertebrados y los anfibios (Normas Mercosur, 2003).

El pescado es el producto fresco de ejemplares sanos y de calidad adecuada para el consumo humano, convenientemente lavado y preservado a una temperatura próxima a la del punto de fusión del hielo. De acuerdo a los componentes anatómicos, se clasifica en:

-Entero: es el pescado entero y lavado,

-Eviscerado: es el producto del pescado fresco, luego de la remoción de las vísceras, pudiendo ser presentado con o sin cabeza, aletas y/o escamas (Normas Mercosur, 2003).

Tabla 2. 1 Clasificación de los peces

Clasificación científica	Características biológicas	Características tecnológicas	Ejemplos
Cyclostomes	Peces sin mandíbula	¿desconocidas?	Lampreas, enredaderas
Chondrichthyes	Pescado cartilaginoso	Alto contenido de urea en el músculo	Tiburones, patines, rayas
Teleostei o pescado óseo	Peces pelágicos	Pescado graso (almacenar lípidos en el tejido corporal)	Arenque, caballa, sardina, espadín
	Peces demersales	Pescado blanco (almacenar los lípidos en el hígado solamente)	Bacalao, eglefino, mero de merluza, lubina

2.2. LA ACUICULTURA

La acuicultura es el cultivo de organismos acuáticos tanto en zonas costeras como del interior que implica intervenciones en el proceso de cría para aumentar la producción. Actualmente, la acuicultura es el sector de más rápido crecimiento para producción de alimentos, representado casi el 50 por ciento de la producción de alimentos del mundo (FAO, 2012).

Una zona de acuicultura consiste en un sistema hidrológico adecuado y que abarca parte de una fuente de captación de agua (lago o represa), área costera o área alejada de la costa, que ha sido destinada al desarrollo de la acuicultura (FAO, 2015). A través de la acuicultura, podemos producir proteínas y alimentos durante todo el año.

La Acuicultura Rural se define como una producción de bajo costo con tecnologías extensivas y semintensivas que se deben adaptar sobre la base de recursos disponibles que poseen los hogares de pequeños agricultores (Edwards y Demaine, 1997). Todo esto implica una cadena de producción integradora y compleja, que tiende a aprovechar al máximo los recursos naturales (Diana *et al.*, 1996).

Un aspecto muy importante a considerar es que Ecuador ha reconocido en la acuicultura una actividad de desarrollo económico con elevado potencial. En este marco, ya se han ejecutado en la zona algunas iniciativas de producción. No obstante, ésta ha carecido de una planificación clara y regulaciones locales para su ordenamiento, y no establece criterios técnicos a largo plazo. Por esta razón un proceso de cooperación de asistencia técnica especializada es importante, ya que se puede convertir en un aporte significativo para un desarrollo sostenible en esta región.

Figura 2. 1 Imagen representativa de la pesca artesanal en Ecuador

Los orígenes de la acuicultura en el Ecuador se remontan al año 1932 cuando en la región de la Sierra se introdujo la trucha (*Salmo gairdneri*) para repoblar lagos, lagunas y ríos. En la actualidad se cuenta con cinco criaderos de los cuales el centro de Chirimachay, en la Provincia del Azuay, está a cargo del Instituto Nacional de Pesca. Este centro cuenta con nueve piletas de incubación y siete de alevinaje con una producción de 100.000 alevines/año. En adición, algunos organismos públicos, pero autónomos, han desarrollado programas piscícolas, como es el caso de PREDESUR (Programa Regional Ecuatoriano para el Desarrollo del Sur), que comenzó en 1976 construyendo seis estaciones piscícolas cuyas funciones son proveer alevines para los programas de extensión e incluyen especies introducidas como tilapias y carpas, añadiendo a la nativa llamada chame para la zona tropical.

En la actualidad encontramos en Babahoyo el centro de investigación Cachari que se dedica a la reproducción de vieja colora y vieja azul, entre otras especies de interés comercial.

La pesquería de peces (suena raro) de agua dulce, como principal fuente de información, pone en evidencia numerosos aspectos como son la disminución

de los desembarques de las principales especies de peces (Vieja colorada, Vieja azul, bocachico, ratón, bio, guanchiche, dica, dama, barbudo, raspabalsas, entro otros). Por otro lado, las investigaciones realizadas por el Instituto Nacional de Pesca (INP) ponen en evidencia que la frecuencia de la ocurrencia en las capturas de las principales especies es cada vez menor, observación coherente con la tendencia en la disminución de los desembarques que realiza el sector pesquero artesanal de esta provincia (Willan Revelo y Esteban Elías, 2004).

Figura 2. 2 Espejo de aguas continentales

Las aguas interiores del Ecuador presentan una riqueza amplia en su ictiofauna que está caracterizada por una gran cantidad de peces y una diversidad de especies. Estas especies han sido objeto de interés científico desde el siglo XIX, cuando las primeras colecciones de peces para estudios taxonómicos fueron hechas por Humboldt (1782), en sus extensos recorridos por Sudamérica. Los estudios fueron continuados por otros investigadores como Wagner (1870), Boulenger (1898), Eigenmann (1922), y más recientemente, Fowler (1943), Bohlke (1958) y Ovchinnyk (1967).

Investigaciones realizadas por el Instituto Nacional de Pesca del Ecuador (Chicaiza, 2005) indican que la frecuencia de captura de las principales especies nativas es cada vez menor, observación coherente con la tendencia a la disminución de los desembarques que realiza el sector pesquero artesanal. Un problema es el incremento poblacional frente a una fuente de producción natural decreciente que no abastece al mercado. Otro problema es la contaminación de las aguas por el uso excesivo de agroquímicos que ha ocasionado la muerte o la alteración en el ciclo productivo de muchas especies piscícolas nativas. Para abastecer en algo la demanda de carne de pescado se han tenido que introducir especies como es el caso de las tilapias de la familia ciclidae, que hasta cierto modo ha venido a diezmar la población de las especies nativas (Revelo y Elias, 2004**)**.

2.3. CARACTERÍSTICAS GEOGRÁFICAS, OROGRÁFICAS, CLIMÁTICAS DE LA PROVINCIA LOS RIOS Y SUS SISTEMAS FLUVIALES

La Provincia de Los Ríos es una de las 24 provincias que conforman la República del Ecuador, situada en el centro del país, en la zona geográfica conocida como región litoral o costa. Su capital administrativa es la ciudad de Babahoyo, mientras la urbe más grande y poblada es Quevedo. Ocupa un territorio de unos 6.254 km², siendo la décimo quinta provincia del país por extensión. Limita al norte con Santo Domingo de los Tsáchilas, por el este con Cotopaxi y Bolívar, al noroccidente con Manabí y al oeste y al sur con Guayas.

Posee un sistema hidrográfico muy denso, considerando el tamaño de la provincia. La mayor parte de sus ríos nacen en la cordillera occidental de Los Andes, y entre ellos destaca el río Babahoyo, que tiene como afluentes a los ríos Vinces, Zapotal y San Pablo. Posteriormente se une con el Daule para alimentar al rio Guayas. Poblaciones y ríos comparten nombres en la mayoría de los casos como ocurre con Babahoyo, Caracol, Catarama, Ventanas, Vinces o Quevedo.

La Provincia de Los Ríos se encuentra ubicada en el centro de la cuenca del río Guayas, la misma que cubre una superficie de 7205.28 km^2, que equivale al 22.36 % de la superficie total de la cuenca.

El clima en la provincia de Los Ríos no es muy diverso, puesto que en la gran parte del territorio se comporta de manera homogénea. Podemos encontrar los siguientes climas:

Clima Tropical Megatérmico Húmedo

En el extremo Noreste por el cantón Valencia, se caracteriza por registrar únicamente un máximo lluvioso y una sola estación seca muy marcada, acompañada de temperaturas medias superiores a 22°C y lluvias que van desde 1000 mm a 2000 mm., como media anual.

Clima Tropical Megatérmico Semi-húmedo

En el extremo sureste por el cantón Urdaneta , se caracteriza por registrar únicamente un máximo lluvioso y una sola estación seca muy marcada, acompañada de temperaturas medias superiores a 22°C y lluvias que van desde 500 mm a 1000 mm.

Clima Ecuatorial Mesotérmico Semihúmedo

Caracterizado por una precipitación anual de 500 a 2000mm, tiene dos estaciones lluviosas que oscilan entre febrero-mayo y octubre-noviembre, la temperatura media oscila entre los 12 y 20 °C. Éste tipo de clima se presenta en las zonas altas de la parroquia Ricaurte y el cantón Montalvo (Prefectura de los Ríos, 2012).

Figura 2. 3 Mapa de la provincia de Los Ríos

2.4. CARACTERÍSTICAS BIOLÓGICAS DE LA VIEJA COLORADA Y LA VIEJA AZUL.

Se conoce muy poco sobre sus diferentes fases de desarrollo, épocas de desove y factores hidrográficos que los afectan, por tal motivo es de vital importancia la necesidad de obtener información para establecer medidas regulatorias que permitan controlar su explotación (Willan Revelo y Esteban Elías, 2004).

La especie *Cichlasoma festae*, supera los 2000 gramos de peso y una longitud de 25,5 cm, tiene aspecto de una tilapia roja (*Oreochromis* sp) por lo que puede confundirse a simple vista. La especie *Cichlasoma festae* tiene una boca muy protráctil, labios carnosos, dientes cónicos, branquiespinas cortas, estómago expandible, no muy delineado del intestino (Barnhill *et al.*, 1973); una coloración roja intensa desde el inicio de la boca hasta el opérculo, su cuerpo

es de color rojo-amarillo, atravesado en forma perpendicular al dorso por diez franjas negras, la parte frontal de la cabeza es muy pronunciada formando en el macho una joroba. La hembra posee las mismas características del macho exceptuándose la jibá y tiene una forma curva del dorso hasta el hocico. Los juveniles tienen mucha similitud a los juveniles de tilapia (*Oreochromis sp*), destacándose el color gris oscuro en las terminaciones de las aletas pectorales y las diez franjas negras.

Aequidens rivulatus mojarra, es un cíclido de gran tamaño. Los machos pueden alcanzar los 30 cm y las hembras suelen quedarse en los 20 cm. Posee un cuerpo alto y comprimido lateralmente y cuatro o cinco manchas detrás de la mancha lateral (Sifuentes, 1992). Tanto los machos como las hembras tienen en la zona del mentón y la mejilla múltiples líneas de color azul eléctrico y una mancha negra a la mitad del costado (Sifuentes, 1992). Los machos adultos desarrollan con el tiempo una joroba. La hembra es de un color verde oliva sin los reflejos metálicos del macho (Gómez, 2000; Puentes, 2002). Los machos son más atractivos que las hembras exhibiendo un color base verde blanco brillante (Gómez, 2000; Puentes, 2002). Es posible observar que la diferencia entre machos y hembras radica en la forma de las aletas. Los machos poseen la aleta dorsal y anal más larga mientras que la aleta caudal de los machos es reticulada (Goméz, 2000; Puentes, 2002). Tiene múltiples marcas a lo largo de todo el cuerpo de color oscuro formando una especie de líneas punteadas horizontales paralelas a lo largo de todo el cuerpo (Goméz, 2000; Tresierra, 1993). Presentan como todos los cíclidos, la línea lateral interrumpida (Tresierra, 1993).

2.5. CARACTERIZACIÓN MORFOLÓGICA DE LOS PECES

En aras a su identificación y caracterización, así como en el estudio de las variaciones morfológicas acaecidas en los peces como resultado de su adaptación a diversas condiciones medio-ambientales, se han venido utilizando diversas características de los especímenes, entre las que destacan:

- Morfológicas

- Merísticas

El análisis de la morfométria y merística, como técnica ha sido ampliamente utilizado con resultados satisfactorios principalmente en la determinación de procesos microevolutivos en varias especies de importancia comercial (George-Nascimento & Arancibia, 1992; Cortés *et al.*, 1996; Oyarzún, 1997; Hernández *et al.,* 1998).

La morfometría examina el tamaño y la forma del pez usando un rasgo medible, tal como son la longitud estándar, longitud total, distancia del ano, entre otras mediciones. Rasgos merísticos y morfométricos a menudo se utilizan para clasificar los taxones, a veces hasta el nivel de especie o nivel de sub-especies. En las claves dicotómicas, estos conteos y mediciones pueden ayudar a identificar una especie particular de peces. Antes de modernas técnicas genéticas, los caracteres merísticos y morfométricos fueron el fundamento principal para la taxonomía y sistemática de pescado. Incluso hoy en día, caracteres merísticos y morfométricos se utilizan comúnmente para la identificación de especies y análisis genéticos verificación en el terreno.

Con posterioridad a la cuantificación de caracteres morfológicos se desarrolló el sistema denominado Truss network. Esta aproximación se basa en la variación morfológica de las distancias medidas a partir de un entramado entre una serie de hitos o redes corporales, y del recuento de los elementos que componen las estructuras a lo largo, o en partes específicas del cuerpo del pez (Humphries *et al.*, 1981; Strauss & Bookstein, 1982; Bookstein *et al.*, 1985; Winans, 1987; Cadrin, 2000; Fitzgerald *et al.*, 2002). Teóricamente esta caracterización sistemática de la geometría de la forma del pez, aumenta la posibilidad de extraer diferencias morfométricas con un significado biológico dentro y entre especies (Winans, 1987; Fitzgerald *et al.*, 2002).

La evaluación merística recopila rasgos contables, tal como es el número de branquiespinas, número de escamas, número de espinas de las aletas dorsal, caudal, anal y aleta pélvica.

Figura 2. 4 Rayos de la aleta dorsal

Las medidas "tradicionales" propuestas por Hubbs y Lagler (1958) son: longitud cefálica, longitud de la boca, diámetro ocular, distancia interorbital, distancia predorsal, altura máxima del cuerpo, altura del pedúnculo caudal, ancho de la cabeza, distancia interpectoral, ancho de la boca, y longitud del hocico.

Santis *et al.* (2002) realizaron las siguientes medidas en cachama *(Colossoma macropomum)*: longitud estándar, ancho del cuerpo, longitud de la cabeza, altura de la cabeza, altura del opérculo, diámetro del ojo derecho, longitud de la cobertura óptica derecha, apertura de la boca, grosor labio superior, grosor labio inferior, longitud pre-dorsal, longitud base aleta dorsal, altura aleta dorsal, distancia aleta dorsal - adiposa, longitud base de la aleta adiposa, altura aleta adiposa, distancia aleta adiposa - caudal, longitud pedúnculo caudal, ancho pedúnculo caudal, longitud aleta caudal, distancia aleta caudal - anal, longitud base aleta anal, longitud pre-anal, distancia aleta anal - pélvica, longitud base aleta pélvica, longitud aleta pélvica, distancia aleta pélvica - pectoral, longitud base de la aleta pectoral, longitud aleta pectoral.

En los estudios morfométricos tradiciones son diversos los caracteres que se miden. Entre ellos destacan:

Longitud total. Distancia, medida con regla o con pie de rey, desde la parte media del labio superior de la boca hasta el extremo caudal de la aleta caudal.

Longitud estándar. Distancia, medida con regla o con pie de rey, entre la parte central del labio superior de la boca y la base de la aleta caudal.

Longitud de la cabeza. Distancia, medida con regla o con pie de rey, comprendida entre el punto medio del labio superior de la boca y el extremo posterior del opérculo. Incluye la membrana que bordea el opérculo.

Longitud preorbital. Distancia, medida con regla o con pie de rey, comprendida entre el punto más craneal del labio inferior de la boca y el borde craneal del ojo.

Longitud predorsal. Distancia, medida con regla o con pie de rey, comprendida entre el punto más craneal del labio inferior y el inicio de la primera espina del dorso.

Longitud preventral. Distancia, medida con regla o con pie de rey, comprendida entre el punto más craneal del labio inferior y el inicio de la primera espina de la aleta ventral.

Longitud preanal. Distancia, medida con regla o con pie de rey, comprendida entre el punto más craneal del labio inferior y el inicio del orificio anal.

Longitud de aleta pectoral. Distancia, medida con regla o con pie de rey, entre el punto más craneal de la base de la aleta al extremo posterior del mayor de los radios.

Longitud de hueso faríngeo. Distancia, medida con regla o con pie de rey, desde el punto más craneal de la base de la aleta al extremo caudal de la aleta anal.

Altura máxima del cuerpo. Distancia, medida con regla o con pie de rey, comprendida entre el punto más craneal de la aleta pectoral y la línea lateral.

Base de aleta dorsal. Distancia, medida con regla o con pie de rey, desde el punto más craneal de la base de la aleta al extremo caudal de la aleta dorsal.

AC1. Diámetro dorso-ventral del cuerpo, medido con pie de rey, a nivel del primer radio de la aleta dorsal.

AC2. Diámetro dorso-ventral del cuerpo, medido con pie de rey, a nivel del primer radio de la aleta anal.

AC3. Diámetro dorso-ventral del cuerpo, medido con pie de rey, a nivel del primer radio de la aleta caudal.

Grosor cabeza (LC1). Distancia, medida con regla, entre el lado derecho e izquierdo a nivel del punto más caudal de la cabeza.

Grosor tronco (LC2). Distancia, medida con pie de rey, entre el lado derecho e izquierdo a nivel del punto más craneal de la aleta anal.

Grosor cola (LC3). Distancia, medida con pie de rey, entre el lado derecho e izquierdo a nivel de la última espina del dorso.

P1. Perímetro del cuerpo, medido con cinta métrica, a nivel del primer radio de la aleta dorsal.

P2. Perímetro del cuerpo, medido con cinta métrica, a nivel del primer radio de la aleta anal.

P3. Perímetro del cuerpo, medido con cinta métrica, a nivel del último radio de la aleta dorsal

Entre las medidas merísticas que se realizaron se encuentran:

- Rayos espinosos de las aletas dorsal, pectoral, anal, pélvica y caudal
- Radios de las aletas dorsal, pectoral, anal, pélvica y caudal
- Número de escamas de la línea dorsal

Figura 2. 5 Aletas pélvica, pectoral, anal, y caudal

Figura 2. 6 Aletas Dorsal

Simon *et al.* (2010) realizaron un estudio merístico que consistió en la cuenta de radios de las aletas dorsales, anales y pectorales, además del recuento de las escamas de la línea lateral. En el estudio realizado por Días de Astarloa *et al*. (2007) se contaron, por el lado izquierdo de los ejemplares, el número de radios de las aletas dorsal 1 y dorsal 2, anal, pectoral, y número de escamas de la línea lateral y branquispinas.

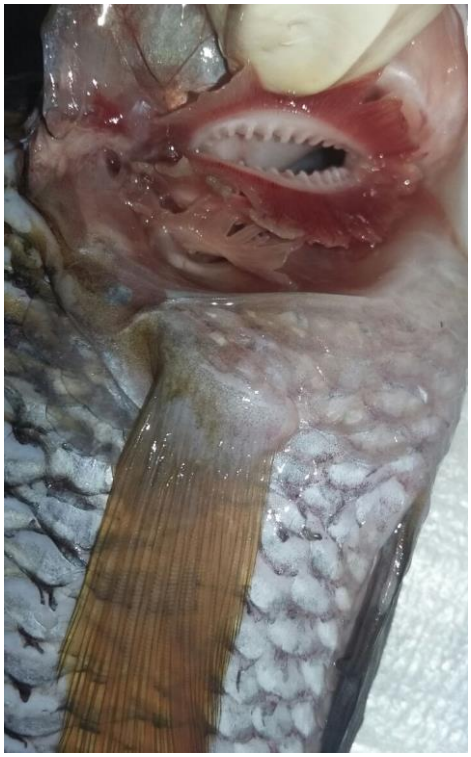

Figura 2. 7 Detalle de branquispinas

2.6. PERPECTIVAS DE LA ACUICULTURA EN ECUADOR

Tabla 2. 2 Especies nativas que se encuentran en las cuencas y subcuencas de la provincia de los Ríos.

Familia	Nombre científico	Nombre vulgar
Anostomidae	*Leporinus ecuadoriensis,*	Ratón
Cetopsidae	*Cetopsogiton* occidentalis	Ciego
	Rhamdia cinerascens	Barbudo
Curimatidae	*Curimatorbis* boulengeri	Díca
Characidae	Brycon *dentex*	Dama
Cichidae	*Aequidens rívulatus*	Vieja azul
	Cichlasoma festae	Vieja colorada
	Oreochromís niloticus	Tilapia negra
Erythrinidae	*Hoplias microlepis*	Guanchíche
Eleotridae	*Electris picta*	Guabina
Gobidae	*Dormitator latiforms*	Chame
Loricanidae	*Plcostomus spinosissimus*	Campeche
Prochilodontidae	*ichthyolephas humeralis*	Bocachico
Centropomidae	*Centropomus unionenses*	Robalo
Pimelodidae	*Pimelodella spp*	Chillo
Sciaenidae	*Cynoscion altipinnis*	Corvina

Tabla 2. 3 Especies nativas silvestres más consumidas por la población.

Nombre común	Nombre científico	Ubicación*
Bocachico	*Ichthyoelephas humeralis*	LR-G-M -E-O-SD
Vieja Colorada	*Cichlasoma festae*	LR-G-M -E-O-SD
Vieja Azul	*Andinocara rivulatus*	LR-G-M -E-O-SD
Chame	*Dormitator latinfrons*	M -E-O-SD -LR-G
Dica	*Curimatorbis boulengeri*	LR-G-M -E-O-SD
Dama	*Brycon dentex*	LR-G-M -E-O-SD
Barbudo	*Rhamdia cinerascens*	LR-G-M -E-O-SD
Robalo	*Centropomus spp.*	LR-G-M -E-O-SD
Sabalo	*Brycon spp*	G- LR-M -E-O-SD
Raton	*Leporinos ecuadorienses*	LR-G-M -E-O-SD
Paiche	*Arapaima gigas*	ZN
Cachama Negra	*Colossoma macropomum*	ZN
Cachma Blanca	*Piaractus brachypomus*	ZN

*G Guayas, M Manabí, LR Los Ríos, O El oro, SD Santo Domingo, E Esmeraldas, ZN Zona Oriental

Tabla 2. 4 Frecuencia de capturas y longitudes (cm).

		Longitudes	
Nª de ejemplares	Promedio	Máxima	Mínima

Dama	683	23.7	37	14
Dicha	1562	17.3	28	12
Guachinche	177	29	20	39
Ratón	451	23.5	42	16
Bocachico	365	21.6	32	13
Barbudo	142	28	37	21
Campestre	155	22.4	57	15
Ciego	73	26.9	37	16
Vieja azul	163	16.2	26	10

Tabla 2. 5 Diversidad y endemismo de peces en la vertiente occidental de Ecuador.

Cuenca	Número de especies presentes	Número de especies endémicas	Porcentaje en la cuenca	Porcentaje en la región	Porcentaje en la vertiente
San Juan y Mira-Mataje	33	5	15,2	5,9	4,5
Santiago-Cayapas	62	15	24,2	17,6	13,4
Esmeraldas	65	17	26,2	20,0	15,2
Total región Norte	**85**	**25**	**29,4**	-	**22,3**
Guayas	70	24	34,3	31,2	21,4
Santa Rosa	32	5	15,6	6,5	4,5
Catamayo	23	2	8,7	2,6	1,8
Total región Sur	**77**	**26**	**33,8**	-	**23,2**
Total	**112**	**43**	**38,4**	-	**38,4**

Tabla 2 6 Distribución emprendimientos piscícolas en Ecuador.

Zona	Nº de piscicultores	Porcentaje
Región Amazónica	4139	77.98
Región Interandina	781	14.71

Región Costa	388	7.31
TOTAL	5308	100

Fuente: Subsecretaría de Acuicultura, 2010.

2.7. CALIDAD DEL PESCADO

El pescado es una fuente importante de nutrientes como las vitaminas A, B y D, calcio, hierro y yodo, al mismo tiempo que proporciona aminoácidos vitales que a menudo carecen otros alimentos básicos como arroz o mandioca. Por lo tanto, es vital para la seguridad alimentaria de muchos de las personas pobres del mundo, especialmente en las zonas costeras y en los pequeños estados insulares en desarrollo.

2.7.1. Técnicas de sacrificio del pez

Este sacrifico puede llevarse mediante diferentes técnicas atendiendo siempre a criterios de bienestar animal. Garantizar el bienestar animal se ha convertido en un hecho cada vez más importante. Las prácticas adecuadas de manejo, los métodos de sacrificio y el equipo deben ser utilizados siempre que sea posible (EFSA, 2009). Una forma de evaluar el bienestar en estos casos es describir el comportamiento de los peces y el estrés durante el proceso.

2.7.1.1. Muerte por asfixia

La asfixia es utilizada tradicionalmente para el pescado capturado, y consiste en dejar al pez fuera del agua hasta su muerte. Este es el método de sacrificio de los peces más usual y se caracteriza por un período de sufrimiento prolongado antes de la muerte. El tiempo que toma el pescado para morir depende de la resistencia a la hipoxia (Bagni *et al.*, 2002; Poli *et al.*, 2002).

2.7.1.2. Muerte en hielo

Después de la captura, los peces se transfieren directamente a las tinas de agua / hielo, utilizando diferentes relaciones de agua / hielo para obtener hielo líquido. Este sencillo y rápido procedimiento se utiliza en los países mediterráneos en distintas especies y en el Reino Unido para la trucha arco iris. La temperatura corporal del pez disminuye rápidamente, así como también su tasa metabólica y los movimientos (enfriamiento en vivo). Los requerimientos de oxígeno en los peces también disminuyen marcadamente y el tiempo de muerte se puede prolongar. Los peces mueren de anorexia (Wall, 2001; Lambooij *et al.*, 2002).

2.7.1.3. Muerte por electrocución

En un recipiente con agua dulce, se aplica corriente eléctrica a los peces, los cuales son aturdidos inmediatamente. La duración del aturdimiento depende de la intensidad y longitud de la corriente (Van der Vis *et al.*, 2003).

2.7.1.4. Muerte por dióxido de carbono

Los peces se colocan en un baño de agua saturada por CO_2 que se disuelve en agua dando H_2CO_3.Esto ejerce un efecto reductor sobre la sangre y pH, de esta manera causa un efecto tóxico sobre el cerebro. Esta reacción es rápida y violenta, se alcanza entre 2-4 min, pero se ha demostrado que el pescado todavía permanece consciente hasta el momento del aturdimiento, variando según las especies de peces (Robb *et al.*, 2000; Poli *et al.*, 2002).

2.7.1.5. Muerte por aturdimiento o percusión

Los peces se capturan manualmente y se los aturde con uno o dos golpes en el cerebro usando un palo de madera o plástico. Si la energía del golpe es suficiente hay una destrucción cerebral masiva y una insensibilidad inmediata en los peces. El sangrado que sigue asegura la muerte del pez y mejora la calidad de la carne. Este método no se aplica fácilmente porque el golpe debe

ser preciso y con personas bien entrenadas (Robb *et al*., 2000; Van der Vis *et al*., 2001; Wall 2001).

2.7.1.6. Muerte por punción en el cerebro

Este método consiste en la destrucción del cerebro, con una punta afilada insertada a través del cráneo y haciendo movimientos en el cerebro para destruirlo. El aturdimiento es inmediato, el método es rápido y eficiente sólo si está bien aplicado. Si a los peces no se le incrusta bien el cuchillo sufren durante el procedimiento (Robb *et al*., 2000; Van der Vis *et al*., 2001; Lambooij *et al*., 2002).

2.7.2. Rigor mortis

Tras la captura del animal, los procesos bioquímicos que permiten mantener la homeostasis se mantienen durante cierto tiempo. Con la ausencia de oxígeno y energía se produce la unión entre las moléculas de actina y las de miosina originando el complejo actina-miosina que lleva a la rigidez del músculo y al fenómeno que se conoce como *rigor mortis* (Oetterer *et al*., 2014). En el momento de la muerte, el músculo es relajado, blando, y tiene una estructura elástica. A medida que se desarrolla el proceso de rigor, la musculatura de los peces se vuelve cada vez más dura y rígida. En salmón del Atlántico rayado (Salmo salar), el rigor mortis se produce después de 2 a 4 h post mortem. Si se evita el estrés antes de la muerte, el rigor se da posteriormente entre 20 a 25 h (Erikson, 2001).

Por otra parte, se observa una mayor resistencia mecánica en el músculo de pescado durante el rigor (Nakayama, 1992). Durante el curso de rigor, los filetes cambian su tamaño geométrico ya que se contraen longitudinalmente (Connell, 1990; Sørensen, 1997). El grado de contracción de los peces varía según su especie y en la forma en que se manipulen. Los encogimientos son típicos en el bacalao del atlántico (*Gadus morhua*) y los filetes se encojen aproximadamente entre un 7% (Karl, 1997) y un 25% (Connell, 1990). Skjervold (2001a) encontró una reducción del 8% al 11%, después que se completó el rigor.

La utilización de cámaras permite registrar los cambios en la longitud de la muestra. Stien (2005), en bacalao atlántico, comprobó que después de aproximadamente 29 h postmortem a 4°C, los filetes se habían contraído entre el 15% y 20%, respectivamente; contracciones que se registraron hasta 5 días post mortem.

Estas pruebas también se han realizado en la trucha arco iris (*Oncorhynchus mykiss*) (Stien, 2006) y en el salmón del atlántico (Kiessling, 2004). Basándose en el análisis de imágenes, las contracciones (reducción de longitud) durante el rigor mortis son más elevadas en animales estresados, llegando a un (13,8%); en filetes del salmón fluctuaron entre el 5.4% y el 11.2% (Veiseth, 2006). Para una mayor frescura de los pescados vendidos es necesario que sean sacrificados inmediatamente después de la captura para garantizar que el ATP y el glucógeno no se agote y retrasar durante un período más largo la entrada del rigor mortis (Teixeira *et al*., 2009).

El rigor mortis se puede medir siguiendo el método de Cuttinger (Korhonen *et al*., 1990). Las mediciones se deben realizar colocando el pez en una superficie sólida plana de modo que la parte del cuerpo detrás del extremo posterior de la aleta dorsal quede colgada sobre el borde, sin apoyo.

El ángulo de rigor se calcula como:

$$a = tan^{-1}\frac{x}{y}$$

Donde X es la longitud (cm) del plano horizontal del triángulo rectángulo e Y es la longitud (cm) del plano vertical del triángulo rectángulo.

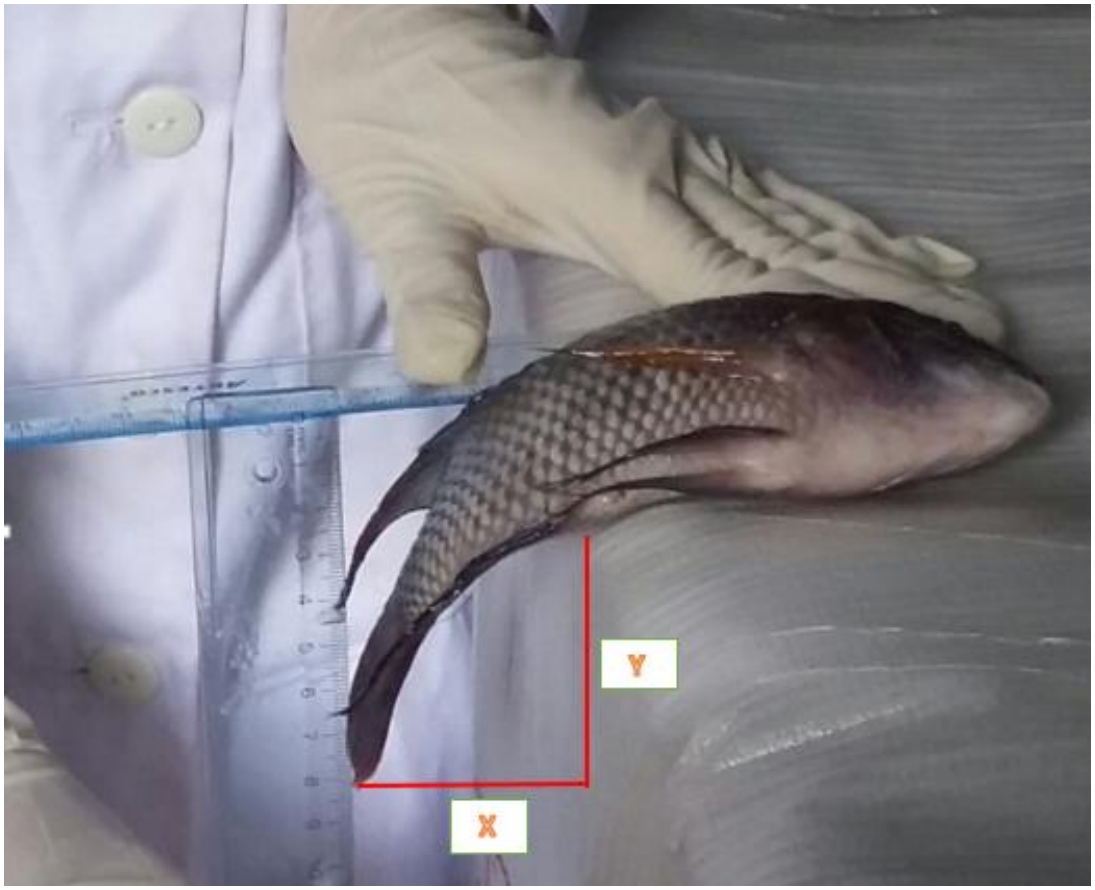

Figura 2. 8 Muestreo de *rigor mortis*

Tabla 2. 7 Comienzo y duración del rigor mortis en varias especies de pescado

Especies	Condición	Temperatura °C	Tiempo desde la muerte hasta el inicio del rigor (horas)	Tiempo desde la muerte hasta el fin del rigor (horas)
Bacalao (*Gadus morhua)*	Estresado	0	2 – 8	20 – 65
	Estresado	10 – 12	1	20 – 30
	Estresado	30	0.5	1 - 2
	Sin estrés	0	14 – 15	72 - 96
Mero (*Epinephelus malabaricus)*	Sin estrés	2	2	18
Tilapia azul (*Areochromis*	Estresado	0	1	

aureus)				
	Sin estrés	0	6	
Tilapia (*Tilapia mossanibical*) pequeña 60g	Sin estrés	0 – 2	2 – 9	26.5
Granadero (*Macrourus whitson*)	Stressed	0	<1	35 – 55
Anchoa (*Engraulis anchoíta*)	Stressed	0	20 – 30	18
Solla *(Pleuronectes platessa*)	Stressed	0	7 – 11	54 – 55
Cangrejo (*Pollachius virens*)	Stressed	0	18	110
Gallineta (*sebastes spp)*	Stressed	0	22	120
Platija japonesa (*Paralichthys olivaceus*)		0	3	>72
		5	12	>72
		10	6	72
		15	6	48
		20	6	24
Carpa (*Cyprinus carpio)*		0	8	
		10	60	
		20	16	
	Estresado	0	1	
	Sin estrés	0	6	

Fuente: Iwamoto *et al*. (1987); Korhonen *et al*. (1990); Hwang *et al*. (1991); Nakayam *et al*. (1992).

2.7.2.1. Cambios *post-mortem*

Tras la muerte, el pescado fresco se degrada debido a la autolisis por enzimas endógenas y crecimiento bacteriano y metabolitos, lo que finalmente hará que los peces no sean comestibles (Richards y Hultin, 2002; Maqsood *et al*., 2012;). Las enzimas endógenas del músculo de los peces son responsables de la pérdida inicial de frescura cuando la autolisis de nucleótidos reduce los olores y sabores deseables de pescado recién cosechado. La estructura y las propiedades físicas del pescado fresco se alteran por la degradación autolítica de las proteínas musculares (Ashie *et al*., 1996; Sivertsvik *et al*., 2002; Olafsdottir *et al*., 2004). Los cambios que ocasiona después de su captura dependen de los factores que afectan las concentraciones de sustratos y los metabolitos de los peces vivos, las actividades enzimáticas, la contaminación microbiológica y las condiciones de captura (Dragonetti, 2008).

2.7.2.2. El estrés

Los cambios en la frescura del pescado también se ven afectados por el estrés. Los cambios observados en peces estresados fueron más manifiestos y por tanto la pérdida de frescura más rápida en comparación con los peces no estresados (Erikson *et al*., 1997; Ådland Hansen *et al*., 2012). Un pez que se estresa antes y durante el sacrificio afecta negativamente a la calidad del pescado. El estrés previo al sacrificio provoca cambios bioquímicos que influyen en la calidad de la carne de animales sacrificados, como el rápido consumo de reservas de glucógeno y ATP y consiguiente la producción de ácido láctico disminución el pH en los músculos (Bagni *et al*., 2007).

El estrés en peces silvestres y de granja, que son muy activos antes del sacrificio, puede afectar la calidad de la carne de los peces de forma física y bioquímica (Robb, 2001). Desde el punto de vista bioquímico, si el pez es muerto después de la actividad muscular, sus células se contendrán más produciendo la respiración anaeróbica y ácido láctico, de tal manera que el trifosfato de adenosina (ATP) se detiene (Korhonen, 1990, Lowe *et al*., 1993). Esto sucede por la caída en la ATP, que es el agente que impide el asentamiento de filamentos finos y gruesos (Boyd, 1984). Einen y Thomassen (1998) sugirieron que la duración del estrés pre-sacrificio afecta la textura, donde el estrés a corto plazo ha demostrado ser el responsable del ablandamiento del músculo del pez, mientras que el estrés a largo plazo aumenta la firmeza muscular.

2.7.3. Composición proximal del pescado

La carne de pescado se compone básicamente de agua (66-81%), proteína (16-21%), carbohidratos (<0,5%), lípidos (0,2-25%) y cenizas (1,2 a 1,5%) (FAO, 1999; Abeywardena, 2011; Dyck *et al.*, 2011), constituyendo una fuente de alimentos de alta calidad (Molina *et al*., 2000; Castro, 2002).

Tabla 2. 8 Composición proximal (%) de los principales de peces

Carne	Humedad	Proteína	Cenizas	Grasa	Referencia
Vieja colorada	79.49	18.46	1.40	1.93	González et al 2016
Vieja Azul	74.65	22.43	1.55	4.17	González et al., 2017
Tilapia nilótica	80.06	13.62	2.06	2.47	Bozaoglu and Bilguven. 2012
Tilapia	78.00	18.64	--	1.93	Lima et al., 2015
Tilapia	74.60	19.1	1.5	2.8	Gutiérrez et al., 2015
Bocachico	72.47	--	--	2.17	Izquierdo et al., 1999
Trucha	77.06	--	--	1.50	Izquierdo et al., 1999
Cachama	70.73	--	--	6.15	Izquierdo et al., 1999
Varios	66-81	16-21	1.2-1.5	0.2-25	Stansby 1962, Love 1970
anguila	60-71	14.4	--	8-31	Murray and Burt, 1969; Poulter and Nicolkaides
Salmon solar	67-77	21.5	--	0.3-14	Murray and Burt 1969; Poulter and Nicolkaides
Prochilodus platansis	67	18	3.4	---	Murray and Burt 1969; Poulter and Nicolkaides
Colossoma macropomum	67.1	18	4.1	--	Murray and Burt 1969; Poulter and Nicolkaides
Colossoma Brachypomum	69.3	15.6	5.8	--	Murray and Burt 1969; Poulter and Nicolkaides

2.7.3.1. Agua

El agua es el componente más abundante en la mayoría de los alimentos y representa aproximadamente el 80% en el músculo del pez magro. Los cambios en la cantidad y propiedades del agua juegan un papel vital en los cambios de calidad que se producen en el músculo de los peces durante el procesamiento y el almacenamiento (Murray y Burt, 2001). El agua afecta a diversos parámetros de calidad tales como la apariencia, textura y almacenamiento de los peces. Según Sikorski (2001), las proteínas miofibrilares son los principales componentes responsables de la unión al agua. Cambios ocurridos en las proteínas musculares durante el procesamiento influyen en la distribución del agua y en el tamaño del agua en todo el músculo, así como la transferencia de masa de influencia y la retención de humedad, lo que influye en la calidad, textura, atributos sensoriales y vida útil del producto.

El agua en la carne de pescado representa del 53-80% del peso total, y es uno de las más variables dependiendo la época del año y la especie y dándose una relación inversamente proporcional entre el contenido de agua y la grasa (Ordóñez, 1998). Participa en la conformación de las proteínas, cuya hidratación es responsable de las propiedades reológicas y la jugosidad del músculo (Suárez, 2006). El peso de un filete representa alrededor del 80% de agua en pescado blanco fresco, mientras que el contenido medio de agua de la carne de pescado graso es de alrededor del 70%. El agua está ligada aproximadamente el 95% dentro de las células musculares. Restringido en sus movimientos moleculares, se inmoviliza por la carga o cadenas laterales hidrofílicas de aminoácidos y fuerzas capilares. Aproximadamente el 80% de agua es inmovilizada por las proteínas miofibrilares y citoesqueléticas (Nollet *et al*., 2009). Entre las fibras sarcoplásmicas, se encuentra aproximadamente el 15% del agua encontrándose parcialmente inmovilizada por la proteína de superficie, agua-soluto, e interacciones agua-agua. Una parte de esta agua es "Libre", significa no unida por cadenas laterales de proteínas, de iones o fuerzas capilares. Sin embargo, este agua se inhibe de fluir libremente fuera de la célula (Nollet *et al*., 2009).

2.7.3.2. Proteína

Las proteínas del músculo del pescado se dividen en tres grupos:

-Sarcoplasmáticas

-Miofibrilares

-Del tejido conectivo.

Las proteínas sarcoplásmicas son muy diversas y se estima que una célula contiene entre 100 y 200 diferentes proteínas sarcoplásmicas y representan el 25-30% del contenido total de proteínas en músculos de pescado (Huss, 1995). La mayoría de las enzimas están conectadas al metabolismo energético, como la glucólisis. Aunque las proteínas sarcoplásmicas son tan numerosas y diversas, tienen algunas cualidades similares. La mayoría tiene pesos moleculares relativamente bajos, un alto punto de pH isoeléctrico y globular. (Xiong, 2000). La mioglobina es uno de los componentes sarcoplasmáticos y es

responsable del color rojo en la carne fresca (Molins, 1991). Son importantes para los procesos bioquímicos que tienen lugar en el músculo post mortem, Incluyendo los procesos de licitación (Xiong, 2000). La actividad específica de diferentes enzimas depende de las especies de peces, así como la estación del año, y la etapa del ciclo de vida, etc. (Nakagawa *et al*., 1988; Søvik y Rustad, 2004, 2005a y b).

La determinación de proteínas sarcoplásmicas por electroforesis se utiliza para diferenciar entre diferentes especies de peces, pero cada especie tiene su patrón de banda característico (Lundstrom, 1980; Nakagawa, 1988). Afectan al pez directa o indirectamente a través de su efecto negativo del color, sabor, textura o su valor nutricional por mencionar algunos. Las proteínas sarcoplásmicas afectan la capacidad de retención de agua en la carne (Den Hertog Meischke, 1997; Wilson y Van Laack, 1999).

Las proteínas miofibrilares representan aproximadamente el 50 y 60% de la proteína total en el músculo de pescado (Shahidi, 1994). Las proteínas miofibrilares juegan un papel importante en la unión del agua en el músculo, pero la cantidad de agua unida a las proteínas depende de la composición de aminoácidos y la conformación de la proteína, la fuerza iónica, y el pH del músculo, entre otros factores. Aproximadamente veinte tipos diferentes de las proteínas miofibrilares son conocidas y se dividen en tres subgrupos según su funcionalidad:

1. Las principales proteínas contráctiles, incluyendo miosina y actina,
2. Proteínas reguladoras, tales como tropomiosina y troponina y finalmente
3. Proteínas citoesqueléticas, tales como titina o conexión (Xiong, 2000).

Las proteínas del tejido conectivo conectan las células musculares, los haces de fibras y los músculos y sirven de apoyo a los huesos, ligamentos y tendones. La proteína conectiva más abundante es la proteína extracelular llamada colágeno. El colágeno es una glicoproteína compuesta de tres cadenas polipeptídicas en una triple hélice de estructura estabilizada por enlaces H. Sato *et al*. (1986) mostraron que un alto contenido de colágeno en el pescado llevó a una mayor flexibilidad del cuerpo y una mayor capacidad de movimiento de natación. Tres capas de tejido conectivo están presentes en el

músculo: endomisio, perimisio y epimisio. El endomisio es la capa de tejido conectivo que envuelve cada fibra muscular. Perimisio es el tejido conectivo alrededor de los haces de músculo, mientras epimisio rodea a todo el músculo. Cada una de estas capas se compone de diferentes tipos de colágeno. El colágeno tipo I, que consta de dos idénticas cadenas y una cadena II, es el componente principal en epimisio. Tipo I y tipo III, que consiste en tres cadenas idénticas III, son los componentes principales en el perimisio en la carne (Xiong, 2000). El tipo de colágeno encontrado en cada tipo de tejido conectivo en la carne y su cadena es el principal componente que sirve como nutriente para la alimentación humana y cuyo contenido representa el 18% del peso total del músculo. El aumento de la concentración de colágeno es probablemente la razón principal de la suavidad de la carne (Roth *et al*., 2005).

Tabla 2. 9 Tipos de colágeno en la carne

Tipo	Cadenas peptídicas	Composición molecular	Pertenencia
I	a^1, a^2	$(a^1(I))$, $a^2(I)$	Piel, tendones, huesos, músculos (epimisio)
II	a^1	$(a^1(II))_3$	Cartílago
III	a^1	$(a^1(III))_3$	La piel fetal, el sistema cardiovascular, las membranas sinoviales, Órganos internos, músculo (perimisio)
IV	a^1, a^2	$a^1(IV)_3$	Membranas basales, cápsula de lente, glomérulos Membrana placentaria, pulmón, músculo (endomisio)
V	aA,aB,aC	$(aB_2$ aA o $(aB)_3$ $+(aB)_3$ o $(aC)_3$	Membrana placentaria, sistema cardiovascular, pulmón, músculo (Endomysium), componente secundario de muchos tejidos.
VI	**a^1, a^2, a^3**	$a^1(IV)$, $a^2(IV)$,$a^3(IV)$	Alrededor y entre las fibras de colágeno y en la superficie de las células

	(Bonaldo et al., 2002)

Fuente: Van der Rest y Garrone, 1991; Belitz y Grosch, 1999; Bonaldo, Russo, Bucciotti, Doliana y Colombatti, 2002.

Tabla 2 10 Porcentajes de aminoácidos en proteína de pescado

Aminoacidos	pescado
Lisisna	8.8
Triptofano	1.0
Histidina	2.0
Fenilalanina	3.9
Leucina	8.4
Isoleucina	6.0
Treonina	4.6
Metionina-cistina	4.0
Valina	6.0

Fuente: Braekkan 1976; Moustgard 1957

2.7.3.3. Grasa

El contenido de grasa del pescado es relativamente más bajo que el registrado en mamíferos vertebrados de consumo humano. (Puwasatien *et al*., 1999) informaron que el músculo de la tilapia contenía 1,8% de grasa. Visentainer *et al*. (2005) y Chaijan (2011) informaron contenidos lipídicos aún más bajos (1.09 y 1.10%, respectivamente), mientras que (Younis *et al*., 2015) registraron valores inferiores al 1% de grasa.

Según el contenido de grasa del músculo, los pescados se clasifican en grasos, semigrasos y magros. Los pescados grasos almacenan los lípidos principalmente en el tejido subcutáneo y en el músculo, aunque en las especies con cantidades muy elevadas de lípidos, también se las encuentra en la cavidad abdominal, y los pescados magros en el hígado y debajo de la piel en pequeñas cantidades.

En la carne del pescado, los depósitos de grasa se encuentran esparcidos por el tejido muscular en forma de gotas de aceite intramusculares, en el músculo rojo, o fuera de las células (Huss, 1995).

La grasa del pescado difiere de los animales de origen terrestre ya que estos presentan un alto contenido de ácidos grasos altamente insaturados (HUFA). Los de la serie omega-3 constituyen el mayor porcentaje y son los que en realidad dan las características primordiales al pescado, siendo los principales el eicosapentaenoico (20: 5n3, EPA) y el docosahexanoico (22: 6n3, DHA). Estos ácidos grasos son precursores con funciones antiinflamatorias, antiarrítmicas y antitrombóticas (Simopoulos, 2005).

2.7.3.1.1. Perfil de ácidos grasos

Ozogul *et al*. (2007) manifiestan que el contenido en ácidos grasos del aceite de pescado contiene: 8.5% de ácido mirístico, 19.4% de ácido palmítico, 10.1% de ácido palmitoleico, 3.9% de ácido margárico, 5.4% de ácido esteárico, 15% de ácido oleico, 3.5% de ácido linoleico, 1.7% de ácido linolénico 1,4% de ácido gadoleico, 11.9% de ácido eicosapentaenoico (EPA), 2.5% de ácido clupanodónico, y 12.9% de ácido docosahexaenoico (DHA).

El hombre, como todas las otras criaturas, sintetiza su propia grasa a partir de la mayor parte de la grasa de los alimentos. Sin embargo, el cuerpo humano a través de medios metabólicos a su disposición, no puede crear doble enlace de carbono más allá de 9. Por lo tanto, los ácidos grasos poliinsaturados deben introducirse necesariamente en el cuerpo a través de alimentos ricos en estos ácidos, los cuales se les llama ácidos grasos poliinsaturados esenciales (AGE) o vitamina F (G. NIACE) (Chakroborty *et al*., 2009).

Los ácidos grasos omega-3 producen numerosos efectos beneficiosos sobre la salud humana, particularmente el EPA y DHA, los cuales han sido perfectamente documentados. El primero de ellos, el EPA, previene enfermedades relacionadas con la circulación sanguínea como la hipertensión, la trombosis cerebral y los ataques de corazón (Lees & Karel, 1990; Simopoulos, 1991). Además, se ha demostrado que este PUFA produce una mejora en la respuesta antiinflamatoria y alérgica del organismo (Uauy &

Valenzuela, 2000). Por otra parte, el DHA desempeña un papel muy importante en el desarrollo del cerebro y la retina (Ward & Singh, 2005). Otros estudios indican el uso de omega-3 PUFA en la prevención de enfermedades mentales (Ross *et al*., 2007) y algunos tipos de cáncer.

Tabla 2. 11 Contenido de ácidos grasos poliinsaturados de cadena larga omega-3 (AGPICL n-3) (g/100 filete)

	EPA (20:5 n-3)	DHA (22:6 n-3)	Referencia
Bocachico	3.1	6.2	Restrepo *et al*., 2012
Tilapia	0.2	3.0	Restrepo *et al*., 2012
Perifiton	1.7	0	Restrepo *et al*., 2012
Vieja colorada	2.3	4.45	González *et al*., 2017
Cachama	19.6	10.0	Izquierdo *et al*., 1999
Trucha	2.0	18.4	Izquierdo *et al*., 1999
Salmonete rayado	6.13	5.47	Öksü *et al*., 2011

2.7.3.1.2. Oxidación de los lípidos del pescado

La gran cantidad de ácidos grasos poliinsaturados que se encuentran en los lípidos de los peces los hace susceptibles a la oxidación por un mecanismo autolítico.

La oxidación de los lípidos puede suceder particularmente si el pez no está bien sangrado (Richards y Hultin, 2002; Maqsood *et al*., 2012). Las grasas en los peces son principalmente los ácidos grasos insaturados que son oxidados fácilmente por el oxígeno de la atmósfera, las altas temperatura o exposición a la luz lo cual puede aumentar la tasa de oxidación. Para los pescados grasos la rancidez es causada principalmente por la oxidación, lo que produce un olor desagradable, así como también un sabor rancio. (Shahidi & Zhong, 2010; Ritter & Budge, 2012).

2.7.4. Composición mineral del pescado

El estudio de los elementos minerales presentes en la vida de los organismos una importancia biológica; ya que muchas de estos elementos intervienen en algunos procesos metabólicos siendo indispensable para todos los seres vivos (Shul'man, 1974). El cuerpo por lo general contiene una pequeña cantidad de estos minerales, algunos de los cuales son nutrientes esenciales, componentes de muchas enzimas del sistema y del metabolismo, como tales contribuyen al crecimiento. Las sales minerales más importantes son el calcio, sodio, potasio, fósforo, hierro, cloro, mientras que muchos otros también se necesitan en trazas. La deficiencia en estos elementos minerales nutritivos principales es que induce al buen funcionamiento del organismo; y al no consumirlos reduce la productividad y provoca enfermedades, como la incapacidad de la sangre para coagularse, la osteoporosis, anemia, entre otras anomalías. (Shul'man, 1974; Mills, 1980).

Tabla 2. 12 Composición mineral de varias especies importantes de peces

Minerales				Rango mg/100g
Hierro	mg / kg	0.62	7%	--
Zinc	mg / kg	1.5	7%	--
Calcio	mg / kg	2.8	8%	19-881
Yodo	g / kg	0.02	10%	--
Selenio	mg / kg	0.02	7%	--
Fósforo	mg / kg	3.3	8%	68-550
Magnesio	mg / kg	0.74	7%	4.5-452
Sodio	mg / kg	2.7	8%	30-134
Potasio	mg / kg	3.3	8%	19-502
Manganeso	mg / kg	0.05	7%	--
Azufre	mg / 100 g	0.02	7%	--
Cobre	mg / kg	0.1	8%	--
Cromo	mg / kg	0.05	10%	--

Fuente: Bogard *et al.,* 2015; Murray and Burt, 1969

2.7.5. Métodos de evaluación de la frescura

Por lo tanto, la necesidad de técnicas analíticas rápidas para evaluar la frescura y la calidad de los alimentos es cada vez mayor. Se han probado muchos métodos y técnicas para evaluar la frescura y deterioro con la finalidad de determinar la calidad de los pescados (Martinsdóttir, 2002; Alasalvar *et al*., 2011). A menudo al pescado se le fija el precio según su frescura, los peces son traídos a lugares de desembarque, donde se clasifica en diferentes grupos de precios y frescura basados en un análisis sensorial (Chebet, 2010).

Tabla 2. 13 Escala de frescura del pescado

Criterios				
	Marcas			
Parte de pescado inspeccionado	3	2	1	0
Piel	Mucosidad acuosa, transparente.	Apariencia Pigmentación brillante pero no lustrosa. Moco ligeramente nublado	Pigmentación en el proceso de convertirse en descoloridos y aburrido. Moco lechoso	Pigmentación opaca Moco opaco
Ojo	Convexo Córnea transparente Pupila negra y brillante	Convexo y ligeramente hundido Córnea ligeramente opalescente Pupila negra y aburrida	Plano Córnea opalescente Alumno opaco	Cóncavo en el centro Córnea lechosa Pupila gris
Branquias	Color brillante Sin moco	Menos de color Trazas leves de mucosidad clara	Descolorarse Moco opaco	Amarillento Moco lechoso
Carne (cortada del abdomen)	Azulado, translúcido, suave, brillante No hay cambios	Aterciopelado, cerosa, sin brillo Color ligeramente	Ligeramente opaco	Opaco

	en el color original	cambiado		
Color (a lo largo de la columna vertebral)	Sin color	Ligeramente rosado	Rosado	Rojo
Órganos	Los riñones y los residuos de otros órganos deben ser de color rojo brillante, al igual que la sangre dentro de la aorta	Los riñones y los restos de otros órganos deben ser de color rojo opaco; Sangre descolorida	Los riñones y los residuos de otros órganos y sangre deben ser de color rojo pálido	Riñones y residuos de otros órganos y deben ser de color pardusco
		Condición		
Carne	Firme y elástico Superficie lisa	Menos elástico	Ligeramente blando (flácido), menos elástico Superficie cerosa (aterciopelada) y mate	Suave (flácido) Escamas fácilmente desprendidas de la piel, superficie bastante arrugada, inclinada a harina
La columna vertebral	Rompe en lugar de alejarse	Palos	Palitos ligeramente	No se pega
Peritoneo	Se pega completamente a la carne	Palos	Palitos ligeramente	No se pega
		Olor		
Branquias, Cavidad abdominal de la piel	Algas marinas	No hay olor a algas ni malos olores	Ligeramente amargo	Agrio

Fuente: EEC (1976) Council Regulation No. 103/76 freshness ratings. Off. J. *Eur. Communities* No. L20

2.7.5.1. Evaluación sensorial.

La evaluación sensorial de la frescura según (Howgate *et al*., 1992) puede dividirse en cuatro fases:

Fase 1. El pescado fresco tiene un sabor dulce y olor a algas muy suave y delicado. El sabor puede ser levemente metálico, el sabor dulce maximiza dos o tres días después de la captura.

Fase 2. Se pierde el olor y sabor característico. La carne se vuelve neutra pero no tiene sabores desagradables. La textura sigue siendo atractiva para las personas.

Fase 3. Hay signos de deterioro y se produce una variedad de sustancias volátiles y de olores desagradables dependiendo de la especie y tipo de deterioro (aeróbico o anaeróbico). Al comienzo de la fase el sabor desagradable puede ser ligeramente ácido y amargo, especialmente en los

pescados con altos contenidos de grasas, posteriormente un olor sulfuroso y rancio.

Fase 4 Los peces pueden caracterizarse como estropeados o podridos.

La calidad de la carne de pescado depende de sus cualidades sensoriales y puede ser evaluada por diversos métodos que pueden ir desde las sensoriales hasta las instrumentales. Son escasos los trabajos de calidad de la carne en peces de agua dulce (Rodríguez *et al*., 1999).

Los cambios sensoriales son los que percibimos a través de los sentidos, por ejemplo, apariencia, olor, textura y sabor. Los primeros cambios sensoriales del pescado durante el almacenamiento están relacionados con la apariencia y la textura. El sabor característico de las especies normalmente se desarrolla durante los dos primeros días de almacenamiento en hielo (Sigholt *et al*., 1997; Huss, 1999).

El deterioro de los peces después del sacrificio puede detectarse por análisis sensorial, que involucra los sentidos humanos como son la vista, el tacto, olor y sabor para observar cambios en la apariencia del producto evaluado (Teixeira *et al*., 2009). Es uno de los métodos más importantes para evaluar la frescura y la calidad en el sector pesquero. Los métodos sensoriales, ejecutados de manera apropiada, son una herramienta rápida y segura, proveyendo información unificada sobre los alimentos (Hyldig *et al*., 2007).

La evaluación sensorial puede ser practicada a diferentes niveles en el procesamiento pesquero, tales como después del desembarco, al arribo a la planta (entero), a la recepción, o en salas de procesamiento de las factorías pesqueras; evaluación de los filetes crudos enfriados o cocidos, en el momento de su recepción o en las salas de procesamiento de las factorías pesqueras, o en lugares de venta (Martinsdóttir, 2002; Hyldig *et al*., 2010).

La evaluación sensorial se define como la disciplina científica utilizada para evocar, medir, analizar e interpretar reacciones a características de los alimentos como se perciben a través de los sentidos de la vista, olfato, gusto, tacto y oído.

El análisis sensorial integra 4 actividades principales:

1. **Provocar**

Los métodos de análisis sensoriales establecen normas para la preparación y el servicio de las muestras bajo condiciones controladas

Normas UNE 87-004-97:

- Jueces ubicados en cabinas individuales para que emita su propio juicio
- Muestras marcadas aleatoriamente para que la identificación de la muestra no perturbe el juicio.
- Productos presentados en orden aleatorio y diferente a los participantes para equilibrar el posible efecto del orden de presentación de las muestras.

2. **Medir**

- La evaluación sensorial es una ciencia cuantitativa en la cual los datos numéricos son recogidos para establecer relaciones entre las características de los productos y la percepción humana
- Se emplean técnicas de la investigación de la conducta y la psicología experimental observando y cuantificando las respuestas humanas.

3. **Analizar**

- El análisis adecuado de los datos generados por los observadores humanos que son a menudo altamente variables
- Los métodos estadísticos de análisis de los resultados, porque un panel de catadores es un instrumento muy heterogéneo para la generación de resultados

4. **Interpretacion de resultados**

- El analista en análisis sensorial debe contribuir con sus interpretaciones a clarificar los resultados y debe conocer las limitaciones del método utilizado y los riesgos y el alcance del análisis
- Deben ser profesionales preparados para realizar la apropiada interpretación de los resultados.

2.7.5.2. Bases volátiles nitrogenadas totales (BNVT) utilizados como índice de frescura.

Se han sugerido diversas cifras de N-BVT relacionadas con la calidad del pescado; clasificando al pescado en tres categorías:

Clase I: N-BVT < 30 mg/100 g

Clase II: 30 mg/100 g < N-BVT < 40 mg/100 g

Clase III: N-BVT > 40 mg/100 g (un pescado que presenta estas cantidades no sería apto para el consumo humano).

La duración de cada etapa puede variar, esto dependerá de las condiciones de almacenamiento, especialmente la temperatura que tiene una gran influencia en estos procesos.

TVB-N ha sido ampliamente utilizado como un indicador de deterioro de la calidad del pescado. Fraser y Sumar (1998) indicaron que el catabolismo bacteriano de aminoácidos en peces es el resultado de la acumulación de amoníaco y otras bases volátiles. Las variaciones en el contenido de TVB-N de los filetes de trucha arco iris almacenados a 3 y -3 °C inicialmente, el valor TVB-N era 11.39 mg / 100 g, similar a lo manifestado por (Chan, Shwu, & Chieh, 2002; Lu *et al*., 2009) que indicó que el valor inicial de la tilpia era 12.62 mg / 100 g, aumentando más fuertemente durante el almacenamiento. Por lo tanto, la temperatura de almacenamiento desempeña un papel importante en el control de TVB-N: la acumulación de pescado hace aumentar los niveles a 19.34 mg / 100 g – 20.72 mg / 100 g. de TVB-N.

Tabla 2. 14 Contenido de compuestos nitrogenados

mg/100g de peso húmedo	Bacalao	Arenque
Extractivos totales	1200	1200
Total, de aminoácidos libres	75	300
Creatina	400	400
Betaina	0	0
Oxido de trimetilamina	350	250
Anserina	150	0
Carnosina	0	0

Urea	0	0y

Fuente: Shewan, 1974

2.7.5.3. Método del Índice de Calidad (QIM)

El Índice de Calidad (QIM) es una herramienta importante que puede utilizarse para evaluar la frescura del pescado. Este método implica la evaluación de diversas características relacionadas con la calidad, como son la apariencia, textura, ojos, branquias y abdomen. Cada atributo recibe una puntuación que puede variar de cero a dos, o de cero a tres y cuanto mayor sea el puntaje, mayor será el grado de deterioro (Teixeira *et al*., 2009). La industria ha desarrollado una nueva herramienta, mediante la cual se realiza una evaluación de forma sistemática y segura con un método objetivo de evaluación de la calidad, llamado el método del índice de calidad (QIM) (Martinsdóttir *et al*., 2001).

Tabla 2 15 Método QIM para Vieja colorada y azul

Parámetros de calidad		Descripción	Puntuación
Aspecto	Piel	Pigmentación rojo y azul brillante	0
		Algo decolorándose menos colorada y azulada	1
		opaco	2
	Firmeza	En rigor	0
		Firme elástico	1
		Blando	2
		Muy blando	3
Ojos	Cornea	Clara	0
		Opalescente	1
		Lechosa	2
	Forma	Convexa	0
		Plana ligeramente hundida	1
		Hundida cóncava	2
	Pupila	Negra	0
		Opaca	1

		Gris	2
		Brillante	0
	Color	Menos coleada llegando a ser incolora	1
		Decoloración, machas marrones	2
		Marrón descolorido	3
		Fresco algas verdes	0
	Olor	Neutro herbal, mohoso	1
Agallas		levadura pan cerveza leche aria	2
		Ácido acético sulfúrico muy agrio	3
		Claro	0
	Mucus	Lechoso	1
		Lechoso oscuro opaco	2
Musculo		Traslucido blanco	0
Filete	Color	Ceroso lechoso	1
		Opaco amarillento manchas marrones	2
		rojo	0
Sangre	Color	Rojo oscuro	1
		Marrón	2
Índice de calidad			0-23

Fuente: Martinsdóttir 2004; Esteves y Aníbal 2006.

2.7.6. Parámetros de calidad de la carne

2.7.6.1. pH del músculo

El pH es uno de los parámetros principales para considerar la calidad de la carne, porque afecta a varias de sus cualidades (color, capacidad de la retención de agua, etc.). El pH está definido como el logaritmo negativo de la concentración de protones. Tiene una escala entre 0 y 14. Un valor de pH por debajo de 7 es considerado como ácido, y por encima de un valor de 7 se considera alcalino o también denominado básico. El pH del músculo de animales sanos y vivos es alrededor de 7.05. Este valor se reduce a medida que trascurre el tiempo de muerte del animal, principalmente, debido a la degradación del glucógeno a ácido láctico, una reacción en la que el músculo trata de producir energía en ausencia de oxígeno. Esta reacción, depende de la actividad de una serie de enzimas que son sensibles a la temperatura, por lo que es importante considerar la temperatura del músculo para hacer la medida del pH.

El pH del músculo bajo en el período inicial refleja el buen estado nutricional del pescado. El pH típico de músculo de pescado vivo ≈ 7.0. El aumento en los valores de pH de 6.2 a 6.8 después de un período inicial refleja la producción

de metabolitos bacterianos alcalinos que estropean el pescado y aumentan el nitrógeno básico total volátil (TVBN) (Kyrana *et al*., 1997).

Después del sacrificio, uno de los cambios más significativos del músculo es la caída en el pH provocado por el estrés a corto plazo que va desde 6.75 a 6.54 (Bello & Rivas 1992; Skjervold *et al*., 2001). Otro de los efectos observados es una alta variación en los niveles de glucógeno que conducen a una alta variación en pH final que oscilan entre 5.9 y 6.6 (Gines *et al*, 2003). Se sabe que el pH bajo asociado con la acumulación de ácido láctico conduce a la textura blanda, la actividad de la catepsina y la pérdida de líquido (Bahuaud, Mørkøre *et al*., 2010). Estudios de la tilapia reflejan que con un pH de 6.4 el pez se encuetra en rigor en un 20% pero a medida que el pH aumenta el rigor tambien lo hace y a valores de 6.85 pH el rigor es del 80 %, por lo expuesto se dice que el pH del músculo influye en la textura del músculo de pescado (Kanasi *et al*., 2015). El estudio hecho por Stien *et al*. (2005) encontraron que el pescado no estresado tenía un pH significativamente más alto de 7.3 que el pescado estresado que fue de 7.0.

Figura 2. 9 Toma de pH

2.7.6.2. Color

Psicológicamente podemos decir que el color es tridimensional, percibiéndolo distinguimos tres atributos:

-Tono o matiz de un color es el atributo de la sensación visual según la cual el estímulo aparece similar a uno de los colores percibidos: rojo, verde, amarillo, verde y azul o a ciertas proporciones de dos de ellos. Se define como la cualidad del color. Está relacionado con la longitud de onda dominante del espectro. Considerando un color como la mezcla de luz blanca y una luz monocromática, la saturación representa la proporción de luz monocromática que existe en esa mezcla. Un color puro es saturado mientras que un color blanquecino o grisáceo, de este modo tenemos colores vivos y apagados.

-Claridad se refiere a la cantidad de luz que se percibe. El gris es el color de los objetos que no presentan otro atributo que la claridad, en una escala que tiene como límites el blanco y el negro.

A los dos primeros se les denomina atributos cromáticos o cromaticidad. Basado en este hecho de la trivarianza visual se ha intentado representar a los colores en un espacio tridimensional cuyas coordenadas estén más o menos correlacionadas con estos atributos.

El color puede ser producido de varias formas:

1- Por un proceso de adición: es el caso de la luz blanca que resulta cuando todos los colores del espectro visible se juntan. La luz blanca también se puede producir por la suma de 3 colores: rojo, azul y verde o por la combinación de un primario más su complementario.

2- El color puede ser producido por absorción selectiva. Cuando sobre un objeto no luminoso se dirige un rayo de luz blanca, parte de esta luz es reflejada, parte trasmitida y parte absorbida y el color del objeto es el que percibe el ojo cuando le llega la luz reflejada o la luz transmitida, con su correspondiente distribución espectral.

3- A partir de los datos espectrales es posible obtener las coordenadas colorimétricas que nos informarán del color que tendrá un objeto en unas condiciones determinadas de iluminación y para uno de los observadores patrón.

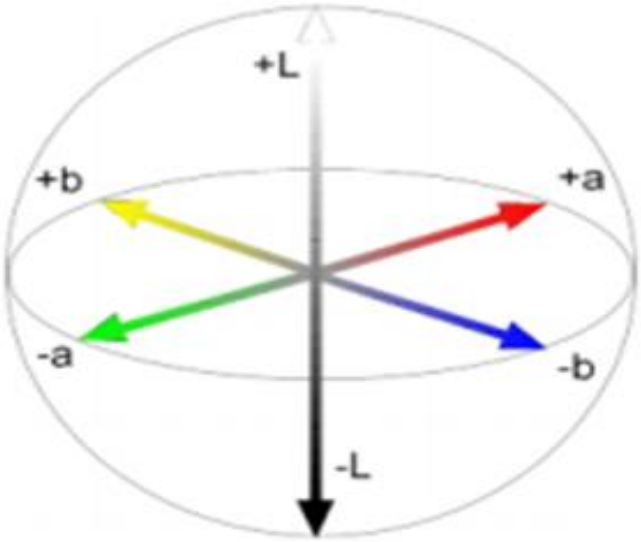

Figura 2. 10 L: Luminosidad, a: + rojo - verde, b: + amarillo -azul

El color del músculo de los peces es un criterio importante cuando los consumidores potenciales evalúan la carne esperando que el pescado blanco de rio sea blanco y por lo tanto puede ser rechazado si el músculo es descolorido. Inicialmente la carne del pescado se encuentra entre 50 a 70 los valores de L^* aumentado su blancura conforme transcurre el tiempo de almacenamiento y se estabiliza entre 70 a 80 a lo largo de todo el período de cosecha (Guillerm- Regost *et al*., 2006).

Los peces suelen tener dos tipos distintos de músculos y éstos se clasifican según el color; una gran masa de músculo blanco y una banda más pequeña de músculo rojo que recorre la longitud del animal justo debajo de la piel (Summers, 2004; Saguer *et al*., 2006). Otros estudios encontraron que los valores de L^* en peces anestesiados y estresados reflejaban valores de L^* 30 y 34 tendiendo a blanco los estresado; los valores de a^* de -1.8 a -1.1 con tendencia a menos verde y valores de b^* 0.9 a -1.3 con tendencia azulado lo cual refleja el efecto del stress en el color de la carne de los peces desmejorado su calidad (Eriksom y Misimi, 2008). Generalmente en especies de peces blancos, el 90% del músculo esquelético del pez se compone de fibras anaerobias blancas, lo que da a la carne su color claro característico (Johnston, 1980, 1981, 1983). En el músculo del atún y otras especies de peces oscuros el nivel de proteínas de hemo (mioglobina y hemoglobina) es

alta, lo que causa el atractivo color rojo del músculo (Schubring, 2008). Por el contrario, las especies de salmónidos tienen la capacidad de depositar carotenoides de su dieta., lo que le da músculo una coloración de carne roja distintiva (Johnston, 1980, 1981, 1983; Shahidi *et al*., 1998; Summers, 2004; Saguer *et al*., 2006; Schubring, 2008).

El color afecta las decisiones de compra de los consumidores y la aceptación del producto (Francis, 1995). El color muscular puede depender del estado de oxidación de las proteínas hepáticas y de la presión de oxígeno en el paquete de alimentos determina qué estado de oxidación será favorecido durante almacenamiento. La mioglobina y la hemoglobina son los compuestos de hemo más abundantes en el músculo. El efecto de la mioglobina sobre el color de la carne y los cambios de color durante el almacenamiento está bien establecido en la literatura (Mancini y Hunt, 2005). Para la mayoría de las diferentes especies de peces, la cantidad de proteínas de hemo en el filete es pequeña debido a la naturaleza anaerobia del músculo. La concentración de hemoglobina en el músculo de los peces puede ser más de la mioglobina (Richards y Hultin, 2002). Los estudios realizados por Stiem *et al*. (2005) demuestran que el musculo de pescado tiene una variación en sus colores que van desde: 53.62 – 77.4 para L*, 1.74 – 2.99 para tonalidad y 5.09-19.05 para croma.

Además de hemoglobina, los carotenoides como la antoxantina son componentes importantes que influyen en el color del músculo en el salmón cultivado.

El factor principal responsable del cambio de color del filete blanco del pescado es la sangre residual, es decir, la intensidad del color depende del contenido de hemoglobina (Hb) y del estado químico. (Love, 1978; Mancini y Hunt, 2005; Saenz *et al*., 2008). La sangre residual en el filete de pescado es principalmente un problema estético, pero también puede contribuir y alterar varios otros parámetros de calidad, reducción de la vida útil, oxidación de lípidos, olor rancio, ablandamiento muscular y la pérdida inherente de nutrientes importantes (Pazos *et al*., 2005; Sakai *et al*., 2006; Larsson *et al*., 2007; Pazos *et al*., 2009; Richards *et al*., 2009; Maqsood y Benjakul, 2010). El pre-sacrificio, estrés, malas técnicas de manejo, enfriamiento, y el método de

matanza aumentan la cantidad de sangre residual en el filete perjudicando su color (Roth *et al*., 2005a; Olsen *et al*., 2006; Olsen *et al*., 2008, Roth *et al.*, 2009a, Roth *et al*., 2009b). El control estricto de estos factores puede mejorar la calidad total del producto. El color es un atributo clave para los productos alimenticios y afecta a la percepción de la calidad por parte de los consumidores (Francis 1995). Con respecto al salmón del Atlántico (Salmo salar) este rasgo de calidad es de gran importancia (Shahidi, 1998). Los valores del color registrados en el bacalao por Digre *et al*. (2010) reflejan una variacion en el color fluctuando desde 84.1 a 85 en L^* de -1.2 a 1.8 para b^* y de 18.8 a 20.5 para a^*.

Para los peces, tales como fletán (*Hippoglossus hippoglossus*) y rodaballo (*Scophthalmus maximus*), la blancura es un atributo importante de calidad, donde los filetes frescos cambiarán de un color opaco, azulado o amarillento a lo largo del almacenamiento (Guillerm-Regost, 2006).

Para el pescado de carne blanca, hay muchos factores que pueden alterar el color de la carne, entre los que se encuentran: restos de sangre (Roth, 2007b), contenido de grasa, la oxidación de los lípidos (Ruff, 2002), la temporada de pesca (Haugen, 2006), las condiciones de almacenamiento (Stien, 2005; Guillerm-Regost, 2006), la maduración (Roth, 2007a), y las condiciones de sacrificio (Stien, 2005; Kristoffersen, 2006). Lo reportado por Lima *et al*. (2015) pone de manifiesto que en la carne de tilapia tiene tendencia a ser blanca ($L^* = 52.77$), rosada ($a^* = 2.76$) y amarillenta ($b^* = 5.54$).

Las determinaciones de color se deben realizar sobre la superficie de las muestras, hasta completar un total de nueve determinaciones por cada muestra, siguiendo las recomendaciones de la American Meat Science Association (Hunt *et al*., 1991).

Figura 2. 11 Análisis de colorimetría

2.7.6.3. Pérdidas por goteo y cocción

Pérdidas por goteo

Las pérdidas por goteo corresponden al exudado de líquidos debido a la desnaturalización de las proteínas miofibrilares de las fibras musculares, daño celular, menor solubilidad y agregación de las proteínas (Einen *et al*., 2002).

El estudio realizado por Suárez *et al*. (2008), en truca arco iris, ha demostrado que la carne tiene pérdidas que van desde 1.5% hasta el 5%. Este aumento es progresivo conforme transcurre el tiempo de conservacion. Valores similares han obtenidos otros autores que trabajaron sobre la determinación de vida útil bajo atmósferas modificadas con el róbalo (*Dicentrarchus labrax*) (Torrieri *et al*., 2006). En otras investigaciones realizadas por Daskalova & Pavlov (2015) demostraron que la carpa pierde entre un 1.5 y 1.7% del peso por pérdidas por goteo. Posiblemente estas diferencias se deban al método de aturdimiento

utilizado para el sacrificio de los peces. Otra prueba realizada a las carpas utilizando electricidad como método de aturdimiento evidenció datos superiores para esta especie, comprendidos entre el 2.0 y 3.22% (Daskalova *et al*., 2016).

Pérdidas por cocción

Los trozos de carne deben tener un tamaño de 4 x 2 x 2 cm y se deben colocar en bolsas dobles. La bolsa interior, donde se encuentra la muestra, se perfora para permitir que los jugos de cocción del pescado drenen durante la cocción. La cocción se debe efectuar en un baño de agua calentado a 76 ºC. Cuando las muestras alcanzan una temperatura de 60 ºC en el centro de la muestra serán mantenidas durante 15 minutos (Barnett *et al*., 1991). Las muestras seran pesadas antes y después de la cocción (Barnett *et al*., 1991; Einen *et al*., 2002).

En el estudio realizado por Varga *et al*. (2013), en la carpa, se registraron pérdidas por cocción que alcanzaron entre el 22.74 y 23.86%. Al ser compara la pérdida de cocción de la carne del salmón (19.1%) se comprobó que al aumentar el tiempo de cocinado la pérdida aumentó rápidamente para alcanzar durante los primeros 20 minutos el 23.4%. Después de 2 h de calentamiento, la pérdida fue del 27.67% (Kong *et al*., 2008).

Figura 2. 12 Pérdidas por goteo

2.7.6.4. Otros factores que determinan la calidad

Además de los anteriormente citados, otros factores que intervienen en la calidad de la carne de pescado se recogen en las siguientes tablas:

Tabla 2. 16 Factores intrínsecos de especies de peces

Factores que afectan la tasa de deterioro	Tasa relativa de deterioro	
	Rápido	Lento
Tamaño	Pez pequeño	Pescado grande
pH *post morten*	pH alto	pH bajo
Contenido graso	Especies grasosas	Especies magras
Propiedades de la piel	Piel delgada	Piel gruesa

Fuente: HUSS H H, 1995

Tabla 2. 17 Cambios autolíticos en pescado refrigerado.

Enzima	Sustrato	Cambios encontrados	Prevención / Inhibición
Enzimas glicolíticas	Glucógeno	La producción de ácido láctico, el pH de las gotas de tejido, la pérdida de la capacidad de retención de agua en el rigor muscular de alta temperatura puede dar lugar a que quede boquiabierto	Se debe permitir que los peces pasen a través del rigor a temperaturas tan cerca de 0 ° C como sea prácticamente posible Se debe evitar el estrés de pre-rigor
Enzimas autolíticas, implicadas en la descomposición de nucleótidos	ATP ADP AMP IMP	Pérdida de sabor a pescado fresco, producción gradual de bitters con Hx (etapas posteriores)	Iguales a los anteriores, la manipulación brusca o el aplastamiento acelera la descomposición
Catepsinas	Proteínas, péptidos	El reblandecimiento del tejido que hace el proceso difícil o imposible	Manipulación brusca durante el almacenamiento y la descarga

Quimotripsina, tripsina, carboxipéptidos	Proteínas, péptidos	Autolisis de la cavidad visceral en pelágicos (estallido del vientre)	Problema aumentado con la congelación / descongelación o el almacenamiento de refrigeración a largo plazo
Calpain	Proteínas miofibrillares	Ablandamiento, molidos inducidos ablandamiento en crustáceos	Eliminación de calcio evitando así la activación
colagenasas	tejido conectivo	Boquiabierto "de filetes	Ablandamiento de la degradación del tejido conectivo relacionada con el tiempo y la temperatura del almacenamiento refrigerado
TMAO desmetilasa	TMAO	Endurecimiento inducido por formaldehído de peces congelados almacenan pescado a una temperatura <= -30 ° C	El abuso físico y la congelación / descongelación aceleran el endurecimiento inducido por formaldehído

Fuente: Parkin and Hultin, 1986; Kinostra *et al* 1990; Gill *et al* 1979 y 1992

Tabla 2. 18 Vida media de varias especies de peces de aguas templadas y tropicales conservadas en hielo.

Especies	Tipo de pescado	Días en hielo	
		templado	tropical
especies marinas		2 - 24	6 - 35
Bacalao, eglefino	magro	9 - 15	
pescadilla	magro	7 - 9	
merluza	magro	7 - 15	
brema	Magro / bajo en grasa		10 – 31
Corvina	magro		8 – 22
Pargo	magro		10 – 28
agrupador	magro		6 – 28
bagre	magro		16 – 19
Pandora	magro		8 – 21
Trabajo	magro		16 – 35
Pez espada	Magro / bajo en grasa		21 – 26
Batfish	magro		21 – 24
Suela, solla,	plano	7 – 21	21
platija	plano	7 – 18	
Hipogloso	plano	21 – 24	
caballa	Alto / bajo en grasa	4 – 19	14 – 18
Arenque de verano	Rica en grasas	2 – 6	
Arenque de invierno	bajo en grasa	7 – 12	
sardina	Rica en grasas	3 – 8	9 – 16
Especies de agua dulce		9 – 17	6 – 40
bagre	magro	12 – 13	15 – 27
trucha	bajo en grasa	9 – 11	16 – 24
perca	Magro / bajo en grasa	8 – 17	13 – 32
Tilapia	magro		10 – 27
mójol	magro		12 – 26
carpa	Magro / bajo en grasa		16 – 21
Pescado pulmonar	Magro / bajo en grasa		11 – 25
Haplochromis	magro		6
sábalo	Grasa media		25
Corvina	Grasa media		30
Bagre	Grasa media		25
Chincuna	graso		40
Pacu	graso		40

Fuente: Lima dos Santos, 1981; Poulter et al., 1981; Gram, 1989.

3. MATERIALES Y METODOS

3.1 MATERIALES Y METODOS

3.1.1 Área de estudio

La investigación se llevó a cabo en tres tres áreas del río Babahoyo y tres granjas de peces en la provincia de los Ríos (Ecuador). El área presenta un clima tropical con una temperatura media de 25 °C, una precipitación anual de 2400 mm y una humedad relativa del 82%. La salinidad del agua, tanto en el río como en la piscifactoría, no superó el 0.1%, el pH estuvo entre 7.0 y 7.29, la temperatura varió entre 19.7 ºC en el río y 24.7 ºC en peces cultivados, mientras que el oxígeno disuelto se situó entre 6.8 y 8.9 mg/l en el río y en la granja de peces, respectivamente. Los valores de conductividad fueron de aproximadamente 145 mS/cm.

3.1.2 Recolección de especímenes, muestreo y sacrificio

Doscientos cuatro muestras de peces maduros (siguiendo las reglas descritas por Frost y Kipling 1980, Chávez-Lomelí *et al*., 1988, Konings, 1989), de Vieja Colorada (*Cichlasoma festae*) y Vieja Azul (A. *rivulatus*) que comprende la mitad de individuos por cada especie de hábitat natural (población silvestre) y ambiente cultivado (granjas de peces privadas) se recogieron durante la madrugada durante el mes de mayo de 2016 y 2017 con la ayuda de artes de pesca estándar como el trasmayo y las redes de mano. Dado que el macho y la hembra no podían diferenciarse morfológicamente, no se llevó a cabo el sexaje del pescado muestreado. La recolección de muestras se realizó semanalmente mediante la compra de muestras representativas de las dos poblaciones seleccionadas de pescadores locales (peces silvestres) o de piscicultura (peces cultivados) geográfica natural en el río Babahoyo (Provincia de los Ríos, Ecuador). Los peces cultivados se recolectaron de piscifactorías. Justo después de la captura, los peces se colocaron al mismo tiempo en una mezcla de 40 L de hielo y 40 L de agua (0,8 °C) hasta su aturdimiento y muerte aproximadamente (20 min). Después de la confirmación de la

muerte, se identificaron los peces, y se realizaron mediciones morfométricas y merísticas.

El estudio se realizó de acuerdo a las recomendaciones nacionales ecuatorianas para el manejo de peces, tomando en consideración las normas sobre bienestar animal.

3.1.3 Medidas corporales en Vieja Colorada

Las mediciones morfométricas lineales se tomaron en el lado izquierdo de los peces, por la misma persona con el fin de minimizar el error artificial, y la mayoría de los caracteres morfométricos se midieron siguiendo el método convencional descrito por Morales et al. (1998) y Diodatti et al. (2008). Los peces se midieron utilizando un tablero de medición, cinta métrica y escalimetro digitales graduadas en mm, el pesaje se realizo con un balanza de pesaje electrónico hasta 0.1 g. Las características merísticas se examinaron de acuerdo con Froese y Pauly (2007).

Las mediciones morfométricas registradas en cada uno de los especímenes fueron:

1: longitud total (TL); 2 Longitud estándar (SL); 3: longitud de la cabeza (HL); 4: longitud pre-orbital (PreOL); 5: longitud pre-dorsal (Pre-DL); 6: longitud pre-ventral (Pre-VL); 7: longitud pre-anal (Pre-AL); 8: longitud de la aleta dorsal (DFL); 9: faringe Longitud del hueso (PhBL); 10: cuerpo de altura máxima (MaxBH); 11: Longitud de la aleta pectoral (PFL); 12: longitud de la aleta anal (AFL).

AC1: profundidad corporal en el primer rayo de la aleta dorsal; AC2: profundidad corporal al nivel del primer rayo de la aleta anal; AC3: profundidad corporal al nivel del primer radio de la aleta caudal; P1: perímetro corporal del cuerpo al nivel del primer rayo de la aleta dorsal; P2: perímetro corporal al nivel del primer radio de la aleta anal; P3: perímetro corporal al nivel del último rayo de la aleta dorsal; LC1: anchura de la cabeza; LC2: anchura del tronco; LC3: ancho de cola.

Las medidas meristicas fueron:

Conteo de espinas de la aleta dorsal y anal y conteo de cartílago de la aleta dorsal y anal.

3.1.4 Medidas corporales en Vieja Azul

Se utilizó la técnica morfométrica (Truss Network System) propuesta por Strauss y Bookstein (1982). Se determinaron mediciones de la red de armaduras basadas en 25 puntos anatómicos en el plano lateral izquierdo. Los hitos eran: (1) comisura de la boca; (2) punto más craneal del premaxilar superior; (3) origen de la aleta pélvica; (4) origen de la aleta dorsal; (5) origen de la aleta anal; (6) punto más craneal de la base de la décima espina dorsal; (7) fin de la aleta anal; (8) terminación de la aleta dorsal; (9) origen ventral de la aleta caudal; (10) origen dorsal de la aleta caudal; (11) punto más craneal del pedúnculo caudal; (12) punto más caudal del pedúnculo caudal; (13) terminación de la aleta pectoral; (14) extremo del opérculo; (15) borde craneal del ojo; (16) borde caudal del ojo; (17) preoccipital (aspecto más posterior del neurocráneo); (18) abajo del opérculo; (19) origen de la aleta pectoral; (20) extremo inferior de la cabeza; (21) abertura anal; (22) punto más craneal del premaxilar inferior; (23) terminación de la primera aleta dorsal; (24) fin del último rayo de la aleta anal; (25) fin del radio de la aleta pelviana.

Los meristicos fueron:

Rayos de aleta dorsal, Rayos de aleta pectoral, Rayos de aleta pelviana, Rayos de aleta anal y Rayos de aleta caudal

3.1.5 pH

El pH del músculo se determinó después de la muerte (pH_0), a las 2 horas (pH_2) y 12 horas (pH_{12}) postmortem insertando un electrodo de pH (pH-metro portátil, HI99163, Hanna Instruments Ltd, UK) en el dorso del filete, tras la cabeza. El instrumento se calibró frecuentemente utilizando tampones de pH 4.01 y pH 7.00, y el electrodo también se limpió para obtener resultados consistentes. El pH del músculo se midió por duplicado y se expresó como valor medio de ambas mediciones.

3.1.6 Parámetros biométricos y de rendimiento

En el laboratorio, los peces se mantuvieron en cajas con hielo en las cámaras frigoríficas a 2 ± 1 °C, y se añadió hielo en escamas según se requeria. Los análisis de laboratorio comenzaron 24 h después de la muerte cuando el rigor mortis había pasado en la mayoría de los peces enfriados. Los peces fueron disecados con un bisturí y unas tijeras, y se retiraron y pesaron aletas, escamas, cabeza, entrañas, huesos y carne. Cabeza, tripas, huesos y rendimiento de la carne se calcularon de acuerdo con la metodología propuesta por Rutten *et al*. (2004). Se utilizaron rasgos biométricos como longitud estándar (cm), peso corporal (g), peso corporal eviscerado (g) y peso sin cabeza, vísceras y piel (g), con el fin de estimar el rendimiento a la canal expresado en las siguientes ecuaciones:

Rendimiento de sacrificio (%) = (Peso eviscerado) / (Peso corporal) x 100

Rendimiento canal (%) = (Peso corporal - peso corporal eviserado) / (Peso corporal eviscerado) × 100

3.1.7 Calidad de la carne

Después de 45 minutos de realizar el fileteado, se realizaron las mediciones de color de la superficie en filetes derechos. Se registraron en tres posiciones usando un colorímetro portátil (Lutron RGB-1002 Chroma Meter) equipado con fuente de luz C y un ángulo de observador de 2º, calibrado a un patrón blanco. El perfil de color del sistema L*, a*, b* se midió en todos los peces cosechados. Las variables de color calculadas fueron L*, a* y b* donde L* describe luminosidad (+ L* = blanco, -L* = negro), a* cromaticidad rojo-verde (+ a* = rojo, -a* = verde) y b* cromaticidad amarillo-azul (+ b* = amarillo, -b* = azul) como recomienda CIE (1976). Para cada filete, se realizaron tres mediciones (a lo largo de la longitud del filete) en la parte interior del filete.

La capacidad de retención de agua (WHC) se determinó usando el método descrito por Grau & Hamm (1953) y se midió de dos maneras: pérdida de goteo y pérdida de cocción. Para determinar la pérdida de goteo, se cortaron dos trozos de 10 mm x 10 mm x 20 mm de músculo fresco. Los cubos fueron suspendidos en un alfiler

dentro de una botella de muestra (200 ml), teniendo cuidado de que la carne no toque los lados del plastico y se almacenó durante 24 h a 2 ± 1 °C. La cantidad de goteo medida entre 24 h post mortem, como la diferencia entre la masa de la muestra antes y después, se expresó como un porcentaje de la masa de partida:

Pérdida de goteo (%) = (peso final) / (peso inicial) x 100

Para evaluar la pérdida de cocción, se recortaron las muestras (aproximadamente 30 g), se pesaron antes de cocinar, se colocaron en una bolsa de polietileno y se sumergieron en un baño de agua (JP Selecta, Barcelona, España) a 80 ºC hasta que la temperatura interna de la muestra alcanzó 70 °C. La temperatura se monitorizó repetidamente mediante un termometro de alta temperatura de tipo flexible (Hanna, Instruments, EE.UU.) insertado en el centro geométrico de cada pieza. Una vez que las muestras se enfriaron a temperatura ambiente (aproximadamente 15 ºC) durante 40 min, se volvieron a pesar (después de secar suavemente sobre papel de filtro). El porcentaje de pérdida de cocción se calculó de la siguiente manera:

Pérdida de cocción (%) = (Peso carne cocida) / (Peso carne cruda) × 100

3.1.8 Análisis proximal

Las muestras de músculo se homogeneizaron utilizando un molino a 20.000 rpm. La proteína húmeda, cruda, la grasa total y el porcentaje de cenizas de la carne cruda de pescado, se determinaron de acuerdo con AOAC (2000). El contenido en proteína bruta se midió mediante el método de digestión en bloques (UNE 55-020). Se realizó una calefacción a 550 ºC durante 24 h (ISO R-936) y se determinó el contenido de humedad mediante secado a 102 ºC durante 24 h (ISO R-1442). El porcentaje de grasa se midió de acuerdo con el método de Soxhlet (ISO R-1443) utilizando un Foss Tecator AB Soxtec 2050. Los análisis se determinaron por duplicado, de acuerdo con el valor medio de dos determinaciones y expresado en mg por 100 g de carne cruda.

3.1.9 Análisis de ácidos grasos

El músculo limpio de piel y hueso de cada ejemplar se mezcló y el lıpido total se extrajo con cloroformo / metanol (2: 1 v / v) que contenıa 0,01% de hidroxitolueno butilado (BHT) como antioxidante (Folch *et al*., 1957). El disolvente orgánico se evaporó bajo una corriente de nitrógeno y el contenido de lípidos se determinó gravimétricamente. Alícuotas de los lípidos extraídos se convirtieron en ésteres metílicos de ácidos grasos (FAME) de acuerdo con el procedimiento descrito por Chistie (1993). FAME se separaron e identificaron en un cromatógrafo de gases GC Perkin Elmer Clarus 500 con un detector de ionización de llama (FID) equipado con una columna capilar TR-FAME (30 mx 0,25 mm id, 0,25 µm de espesor de película, Shinwa Inc.), usando helio como Gas portador a un caudal de 0,5 ml / min. La inyección y el detector se mantuvieron a 250 y 260 ºC, respectivamente. La temperatura del horno se programó a 100 °C, seguido por un aumento de 2 °C / min a 220 °C, con un tiempo de espera final de 20 min. Los ácidos grasos individuales se identificaron comparando sus tiempos de retención con los de una mezcla de ácidos grasos estándar Sulpeco 37 (Sigma Chemical Co. Ltd., Poole, UK). Se usó éster metílico del ácido nonadecanoico (19: 0 ME) como patrón interno. Los ácidos grasos individuales (FAS) se expresaron como un porcentaje del total de ácidos grasos identificados y mg / g de tejido muscular crudo de pescado y se agruparon de la siguiente manera: ácidos grasos saturados (SFA), monoinsaturados (MUFA), ácidos grasos poliinsaturados (PUFA) N - 6 y n - 3. También se calcularon los índices PUFA / SFA, DHA / EPA, Σn-6 / Σn-3, aterogenicidad (IA) e trombogenicidad (IT). IA indica la relación entre la suma de los principales ácidos grasos saturados y la de las principales clases de insaturados, siendo las primeras consideradas pro-aterogénicas (favoreciendo la adhesión de los lípidos a las células del sistema inmunológico y circulatorio) y las últimas anti-aterogénicas (inhibiendo la agregación de placa y disminuyendo los niveles de ácidos grasos esterificados, colesterol y fosfolípidos, evitando así la aparición de micro y macro coronarias). Por último, IT muestra la tendencia a formar coágulos en los vasos sanguíneos.

Los índices IA y TI se calcularon utilizando las ecuaciones de Ulbricht & Southgate (1991) como sigue:

IA = ((C18: 0) + (4 x C14: 0) + (C16: 0)) / (PUFA n-6 y n-3) + MUFA) [5]

+ (C16: 0) + (C18: 0)) / (0,5 x MUFA) + (0,5 x PUFA n-6) + (3 x PUFA n-3) + (PUFA n -3 / PUFA n - 6))

3.1.10 Análisis de minerales

Aproximadamente 1 g de carne cruda de pescado se sometió a la mineralización húmeda por el método de Kjeldahl utilizando una mezcla de ácido nítrico y ácido sulfúrico (2: 1, p / p) según Alasalvar *et al*. (2011). El contenido de minerales se determinó por espectrómetro de absorción de plasma usando un 200-DV (Perkin-Elmer, Waltham, EE.UU). Se midieron los siguientes elementos: potasio (K), calcio (Ca), magnesio (Mg), manganeso (Mn), fósforo (P), hierro (Fe), zinc (Zn) y cobre (Cu). Los análisis se determinaron por duplicado, de acuerdo con el valor medio de dos determinaciones y expresado en mg por 100 g de carne cruda de pescado.

3.1.11 Análisis estadístico

Se analizaron un total de 204 muestras de carne de pescado para diferentes parámetros. Se verificó la distribución normal de todos los datos con la prueba de Kolmogorov-Smirnoff y la homogeneidad de las varianzas con la prueba de Levene. Después de la verificación de la distribución normal, se evaluó el efecto del sistema de producción (silvestre y cultivado) sobre las características de la canal y el filete, la composición de ácidos grasos y el valor nutricional usando ANOVA unidireccional con los sistemas de producción como efecto fijo. El tratamiento estadístico de los datos se realizó calculando las medias y el error estándar de la media. Las diferencias se consideraron estadísticamente significativas a $p < 0,05$. Los datos estadísticos se obtuvieron utilizando el software SPSS, versión 15.0 (IBM, Chicago, IL, USA).

4. RESULTADOS Y DISCUSION

4. RESULTADOS Y DISCUSION

4.1. STUDY OF SOME MORPHOMETRIC AND MERISTIC CHARACTERS AND THEIR VARIATIONS BETWEEN TWO DIFFERENT POPULATIONS (WILD & CULTURED) OF VIEJA COLORADA (CICHLASOMA FESTAE) IN TROPICAL ECUADORIAN RIVER.

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STUDY OF SOME MORPHOMETRIC AND MERISTIC CHARACTERS AND THEIR VARIATIONS BETWEEN TWO DIFFERENT POPULATIONS (WILD & CULTURED) OF VIEJA COLORADA (*CICHLASOMA FESTAE*) IN TROPICAL ECUADORIAN RIVER.

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Abstract.

This study was conducted to determine morphometric and meristic characteristics of two populations (wild and cultured) of Vieja Colorada (Cichlasoma festae), in Provincia de los Ríos (Ecuador) and to establish whether populations could be discriminated based on morphometric variability. Twenty-two morphometric and 4 meristic characters were used to test the hypothesis differentiation. Univariate analysis of variance (ANOVA) from 100

adult specimens showed significant differences (P<0.05) for 21 standardized morphometric measurements out of 26 characters among the means of the wild and cultured Vieja Colorada (Cichlasoma festae) populations tested. Cross correlation amongst certain morphometric variables, i.e., body weight, total length, standard length, pre-ventral length, AC1, LC1 and P1 were medium-strong (r≥0.5), while the remaining were weakly correlated (r<0.5). The length-weight relationship and condition factor (K) values were 2.21 and 1.97 (indicating negative allometric growth), and 2.86 and 4.07 (P<0.05) for cultured and wild fish groups, respectively. The condition factor values, which were significantly different from each other, and showed that feeding could be improved in the farms. Both groups were accurately separated (>80% success rate) by linear discriminant functions that included only four morphometric measures.

Keywords: Cichlasoma festae, condition factor, discriminate analysis, length-weight relationship, morphometric characteristics, population

Introduction

The human communities in the coastal as well as inland areas greatly depends on fishery for their incomes and source of animal protein (Espinosa Lemus et al.,2009).

Environmental degradation and habitat destruction have caused the decline of the production of fishery resources from the wild that have diminished greatly (Ajah et al., 2006). It is necessary, therefore, the domestication of certain fish species for intensive cultivation in captivity.

Fish' morphometric study is a powerful tool for characterizing strains and/or stocks of the same species, which involves detection of subtle variation of shape, independent of size. These examinations require exact measurements and counts of fin ray elements. For morphological study, morphometric (refer to measureable structures such as fin length, head length, eye diameter, or ratios between such measurements) and meristic (include almost any countable structure, including fin rays, scales, gill rakers, and so on) characters are used. The morphometric characters are classified into genetically (narrow range), intermediate (moderate range) and environmentally (vast range) controlled characters (Johal et al., 1994). Despite the advent of techniques which directly examine biochemical or molecular genetic variation, the morphometric or

meristic methods continue to play an important role in stock identification even today (Swain and Foote, 1999). The phenotypic plasticity of fish is very high, with greater variances in morphological traits both within and between populations than any other vertebrates. The cause of variation in the morphometric and meristic characters may range from variability to the intraspecific which is under the influence of environmental parameters (Wimberger, 1992). Fish are very sensitive to environmental changes and quickly adapt themselves by changing necessary morphometrics (Cabral et al., 2003; Hossain et al., 2010). Morphometric variation between stocks may be applicable for studying short-term environmentally induced variation (Pinheiro et al., 2005). In addition, while both morphometric and meristic characters respond to changes in environmental factors, their responses are different in some situations and can differ from species to species. Finally, is important to farmers to know the differences between cultured and wild fish of different species; this could lead them to understand the chemical, physical, nutritional and sensorial profiles of the wild animal an try to reproduce it in their cultured products (Orban et al., 2003). In Ecuador, fisheries contribute 7% to the total supply of animal protein, estimated at 391,700 tonnes catches made by capture fisheries in 2011 (FAO 2013). These catches are made by artisanal fishermen in areas of rivers, lakes, ponds, lagoons, gorges and dams. This activity is performed throughout the year in areas of rivers (Muñoz et al., 2014) or between May and January in other inland areas. Among the freshwater species the Vieja Colorada (Cichlasoma festae) (Boulenger, 1899) highlights. It is a teleost fish (Luna-Figueroa, 2000), native to the continental South America, with a high presence in Ecuador. It is among the nine commercially important species that inhabit the inland waters of Ecuador, Colombia and Peru (Revelo and Elias, 2004). It can be found in rivers, lakes, ponds and dams (Pacheco and Chicaiza, 2008) and noted for its white meat, excellent taste and high acceptance in the local cuisine (Barnhill et al., 1973).

In order to produce and preserve this native species, state administration created the Experimental Station Cachari, located in Babahoyo in the province of Los Rios, where the program conservation of native species of the Subsecretaría de Acuacultura of Ministerio de Agricultura, Ganadería,

Acuacultura y Pesca (MAGAP) is currently being developed. In this experimental station, fingerlings were produced for distribution to farmers and repopulate the rivers. According to MAGAP, the cultivation of Vieja Colorada (Cichlasoma festae) is becoming more and more popular due to its good growth rate, fecundity, ease of manipulation, ability to growth under suboptimal environmental conditions, disease resistance and good consumer acceptance.

Understanding the morphometrics of the fish species will enhance the development of cost effective aquaculture protocols, thus increase in productivity. Although the comparisons of the morphology between cultured and wild fishes from several species have already been conducted by a number of authors (Swain et al., 1991; Ponton and Mérigoux, 2000; Solem et al. 2006; Solomon et al., 2015), there is a lack of information on the level of this variation for most tropical fish species. Difference among cultured and wild Vieja Colorada (Cichlasoma festae) stocks based on morphological characters have not yet been studied, and to our knowledge, this is the first such study focused on examining the extent of their morphological variations in cultured and wild environments.

Since this information is vital for the proper management of the fisheries and for optimum utilization of the resources, the present study, therefore, aims at elucidating the morphometrics of Vieja Colorada (Cichlasoma festae) catched in different habitats (cultured and wild). This will help to plan further breeding and conservation strategies for this fish, and improve productivity.

MATERIAL AND METHODS

Study area

The research included three areas of the Babahoyo River and a fish farm in the Province de los Rios (Ecuador). The area presents a tropical climate with an average temperature of 25 °C, an annual rainfall of 2400 mm and a relative humidity of 82%. The salinity of water, both in the river and the fish farm, did not exceed 0.1%, the Ph was between 7.0 and 7.29, the temperature ranged between 19.7ºC in the river and 24.7ºC in cultured fish, while the dissolved oxygen was between 6.8 and 8.9 mg/l in the river and fish farm, respectively. The conductivity values were about 145 mS cm^{-1}.

Collection of specimens, sampling and slaughter

One hundred matured fish samples (following the rules described by Frost and Kipling 1980; Chávez-Lomelí et al., 1988; Konings, 1989), of Vieja Colorada (Cichlasoma festae) comprising fifty individuals from natural habitat (wild population) and fifty from a cultured environment (private fish farms, cultured stock) were collected at dawn over the month of May 2016 with the help of standard fishing gears like cast and hand nets. Since male and female could not be differentiated morphologically, sexing of the sampled fish was not carried out. Specimen collection was performed weekly by purchasing representative samples of the two selected populations from local fishermen (wild fish) or fish farm (cultured fish). Wild fish were caught from three different locations within their natural geographic distributions in Babahoyo River (Provincia de los Rios, Ecuador). Cultured fish were collected from fish farm. Just after catching, the fish were placed at the same time in a mixture of 40 L of ice and 40 L of water (0.8 °C) until the apparent stunning (20 min) was over. After confirmation of death, the fish were identified, and live weighted, morphometric measurements and myristic counts were performed.

The study was carried out according to Ecuadorian national recommendations for the management of fish, taking into consideration the rules on animal welfare.

Body measurements

The lineal morphometric measurements were taken on the left side of fish, by the same person in order to minimize artificial error, and most of the morphometric characters were measured following the conventional method described by Morales et al. (1998) and Diodatti et al. (2008). The fishes were measured using a measuring board, measuring tape and digital calliper graduated in mm, and weighed with an electronic weighing balance up to the nearest 0.1 g. (Figure 1 and 2). Meristic characteristics were examined according to Froese and Pauly (2007).

A total of 25 morphological characters were used which included 21 morphometric variables and 4 meristic variables (dorsal fin rays (DFR), radios

dorsal fin (RDF), anal fin rays (AFR), radios anal fin (RAF) which were directly counted on each specimen.

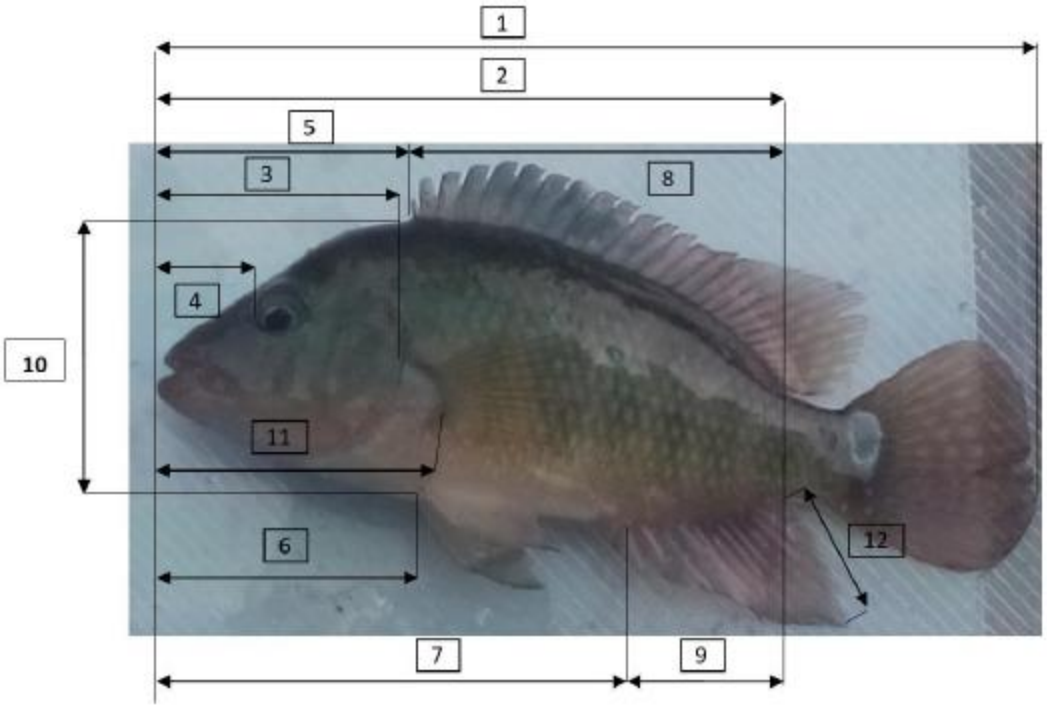

Figure 1. The morphometric measurements registered in each analysed organism (source: own elaboration). 1: total length (TL); 2: standard length (SL); 3: head length (HL); 4: pre-orbital length (Pre-OL); 5: pre-dorsal length (Pre-DL); 6: pre-ventral length (Pre-VL); 7: pre-anal length (Pre-AL); 8: dorsal fin length (DFL); 9: pharyngeal bone length (PhBL); 10: maximum height body (MaxBH); 11: pectoral fin length (PFL); 12: anal fin length (AFL).

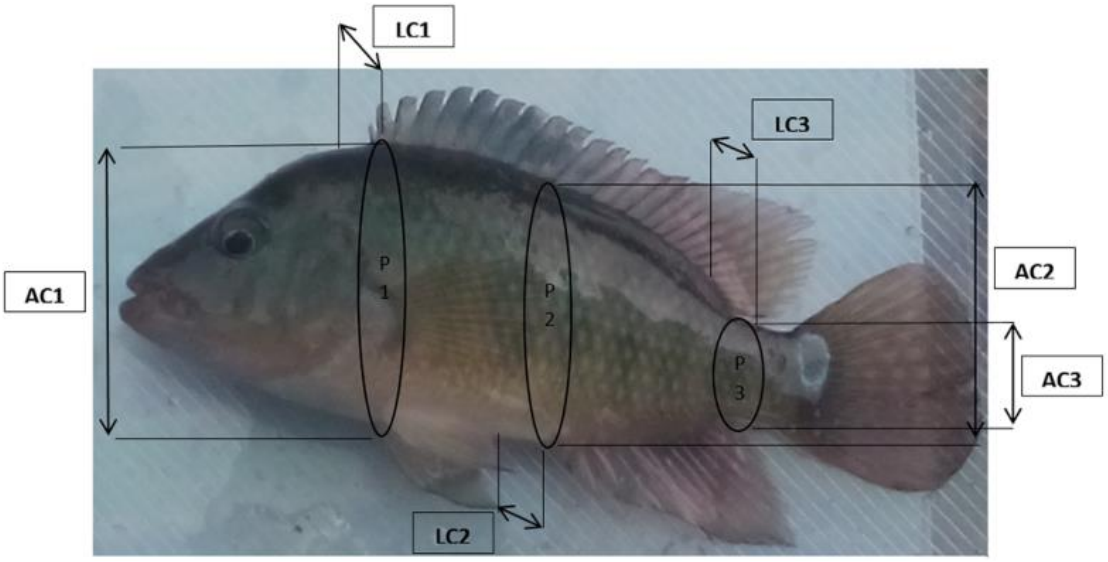

Figure 2. The morphometric measurements registered in each analysed organism (source: own elaboration). AC1: body depth at the first ray of the

dorsal fin; AC2: body depth at the level of the first ray of the anal fin; AC3: body depth at the level of the first radius of the caudal fin; P1: body perimeter of the body at the level of the first ray of the dorsal fin; P2: body perimeter at the level of the first radius of the anal fin; P3: body perimeter at the level of the last ray of the dorsal fin; LC1: head width; LC2: trunk width; LC3: tail width.

The body traits measured were body weight (BW), measured as total weight including gut and gonads; total length (TL, 1), measured with measuring board from the middle of the upper lip of the mouth to the caudal end of the caudal fin; standard length (SL, 2), measured with a calliper, between the central portion of the upper lip of the mouth and the base of the caudal fin; head length (HL, 3), distance, measured with a calliper, the midpoint between the upper lip of the mouth and the rear end of operculum. It includes the membrane that lines the inner seal; Pre-orbital length (Pre-OL, 4), distance, measured with a calliper, between the most cranial point of the lower lip of the mouth and the cranial edge of the eye; Pre-dorsal length (Pre-DL, 5), distance, measured with a calliper, between the most cranial point of the lower lip and the start of the first dorsal spine; Pre-ventral length (Pre-VL, 6), distance, measured with a calliper, between the most cranial point of the lower lip and the start of the first spine of the ventral fin; Pre-anal length (Pre-AL, 7), distance, measured with a calliper, between the most cranial point of the lower lip and the beginning of the anal orifice; Pectoral fin length (PFL, 11), distance, measured with a calliper, between the base point cranial flap to the rear end of greater radii; Pharyngeal bone length (PhBL, 9), distance, measured with a calliper, from the most cranial point of the base of the fin to the caudal end of the anal fin; Maximum height body (MaxBH, 10), distance, measured with a calliper, between the most cranial point of the pectoral fin and the lateral line; Dorsal fin length (DFL, 8), distance, measured with a calliper, from the most cranial point of the base of the fin to the caudal end of the dorsal fin; Anal fin length (AFL, 12), distance, measured with a calliper, from the most cranial point of the base of the fin to the end of anal fin; AC1, body depth, measured with a calliper, at the first ray of the dorsal fin; AC2, body depth, measured with a ruler, at the level of the first ray of the anal fin; AC3, body depth, measured with a calliper, at the level of the first radius of the caudal fin; Head width (LC1, distance, measured with a calliper, between the right and left point level flow side of the head; trunk thickness (LC2), distance,

measured with a calliper, between the right and left at the level of most cranial point of the anal fin side; Thick tail (LC3), distance, measured with a calliper, between the right and left at the level of the last thorn on the back side; P1, body perimeter of the body, measured with measuring tape, at the level of first ray of the dorsal fin; P2, body perimeter, measured with measuring tape, of the body, at the level of the first radius of the anal fin; P3, body perimeter, measured with measuring tape, at the level of last ray of the dorsal fin; Dorsal fin rays (DFR), count of thorns has the dorsal fin from start to finish; Radios dorsal fin (RDF) count of cartilage found in the space between thorns from start to finish; Anal fin rays (AFR), count of thorns has the anal fin from start to finish and Radios anal fin (RAF), count of cartilage found in the space between thorns from start to finish.

Fulton condition factor (K)

The Fulton condition factor (K) which is defined as the well-being of the fish was calculated. K is a useful index for monitoring of feeding intensity, age, and growth rates. The K was calculated with the following formula:

$K = (100 \times BW) / SL3$

where, BW refers to body weight of fish in grams and, SL is the standard length of fish in centimeters

Length-weight relationship

Length-weight relationships were calculated using the allometric regression analysis (Sasi and Berber, 2012). Length-weight was expressed as BW = a*SLb, the logarithm transformation of which gives the linear equation.

$Log\ BW = a + b*log\ SL$

where, BW refers to body weight of fish in grams, SL is the standard length of fish in centimeters, a is the constant being the initial growth index, and b is the growth coefficient. Constant a represents the point at which the regression line intercepts the y-axis and b the slope of the regression line.

Statistical analyses

All statistical analyses were performed using SAS University Edition 3.5 (SAS Institute, Cary, NC). Each collection site was considered a priori as a discrete group. To evaluate if the data have equal variances, a Bartlett test was done

prior to further analyses. Means, standard error, standard deviation, maximum and minimum of all measurements were recorded for each population. The coefficient of variation (CV%) was computed as: CV% = 100×S.D./X, where S.D. is the standard deviation and X is the mean of the measurements of morphometric characters in each population.

The morphometric (continuous) and meristic (discrete) data were analyzed separately. Since meristic characters are independent of size and did not change during growth (Turan et al., 2006), the raw data were used in analysis. However, to avoid possible biases produced by size effects on the morphometric variables, all morphometric characters were standardized by the formula (Elliott et al., 1995)

Madj = M (Ls / Lo) b;

where M is the original morphometric measurement, Madj the size adjusted measurement, Lo the standard length of fish, and Ls is the overall mean of standard length for all fish from all samples for each variable. The parameter b was estimated for each character from the observed data as the slope of the regression of log M on log Lo, using all specimens. This method normalizes the individuals in a sample to a single, arbitrary size, common to all samples and, at the same time, maintains the individual variation (Tudela, 1999). It has been successfully used by many researchers recently (Ibañez-Aguirre and Lleonart, 1996; Salini et al. 2004; Turan et al., 2006). The efficiency of the size-adjustment transformations was assessed by testing the significance of the correlation between a transformed variable and the SL.

Size-adjusted morphometric data and meristic characters were compared by univariate analysis of variance (ANOVA procedure) and Kruskal-Wallis test (NPAR1WAY procedure), respectively, using the group (cultured or wild) as the fixed effect. In addition, the DISCRIM procedure was used to perform a canonical discriminant analysis of both size-adjusted morphometric data and meristic characters. The variables that would be included as predictors in the canonical discriminant function were previously selected with the STEPDISC procedure. The probabilities to enter and to stay in the model were both set at 0.05

Results

Morphometric characters

Morphometric and meristic traits mean values of Vieja Colorada (Cichlasoma festae) from cultured and wild specimens are shown in Table 1.

Table 1. Descriptive statistics of the morphometric and meristic characters (original data) fron Vieja colorada(Cichalasoma festae)

	All data					Cultured		Wild	
	Mean	SD	Min	Max	CV%	Mean	CV%	Mean	CV%
Body weight (g)	90.45	18.16	55.80	152.00	20.07	101.84[a]	16.43	79.06[b]	13.94
Fulton condition factor, K	3.32	0.92	1.23	7.35	27.80	3.01[a]	22.41	3.62[b]	28.65
Total length (cm)	18.27	1.75	12.50	25.00	9.60	19.40[a]	7.17	17.14[b]	7.54
Standard length (cm)	14.14	1.58	9.80	19.00	11.18	15.12[a]	8.00	13.15[b]	9.64
Head length (cm)	5.35	0.48	4.40	6.50	9.03	5.57[a]	8.52	5.14[b]	7.66
Pre-orbital length (cm)	2.18	0.44	1.10	3.80	20.07	2.27[a]	23.43	2.10[a]	14.40
Pre-dorsal length (cm)	5.37	0.67	2.10	6.90	12.44	5.69[a]	7.81	5.05[b]	13.93
Pre-ventral length (cm)	5.83	0.57	4.50	7.40	9.71	6.20[a]	7.94	5.45[b]	6.11
Pre-anal length (cm)	9.05	0.92	5.00	11.00	10.22	9.28[a]	11.98	8.83[b]	7.08
Pectoral fin length(cm)	8.01	0.88	5.80	11.10	10.96	8.25[a]	9.91	7.78[b]	11.32
Pharyngeal bone length (cm)	3.40	0.43	2.50	5.00	12.67	3.52[a]	12.10	3.27[b]	12.25
Maximum body height (cm)	3.90	0.60	2.98	6.00	15.26	4.16[a]	12.91	3.64[b]	14.82
Dorsal fin length (cm)	5.99	0.69	4.90	9.00	11.52	6.40[a]	10.41	5.58[b]	7.53
Anal fin length (cm)	4.58	1.02	2.60	7.20	22.27	4.78[a]	22.15	4.39[a]	21.66
AC1 (cm)	5.46	0.45	4.50	6.90	8.24	5.75[a]	7.04	5.16[b]	4.85
AC2 (cm)	4.93	0.40	4.00	6.10	8.22	5.18[a]	6.53	4.67[b]	6.27
AC3 (cm)	1.94	0.25	1.30	3.10	12.86	2.03[a]	9.73	1.84[b]	14.05
LC1 (cm)	2.31	0.27	1.40	3.20	11.77	2.41[a]	8.79	2.21[b]	13.06
LC2 (cm)	1.56	0.36	1.00	4.00	23.03	1.57[a]	27.45	1.55[a]	17.73
LC3 (cm)	0.71	0.23	0.10	1.70	32.72	0.69[a]	24.43	0.74[a]	38.49
P1 (cm)	13.24	1.00	10.00	16.60	7.55	13.72[a]	8.11	12.76[b]	4.43
P2 (cm)	11.36	0.68	9.50	13.80	6.01	11.78[a]	5.01	10.95[b]	4.51
P3 (cm)	4.73	0.44	3.70	7.00	9.41	4.87[a]	9.63	4.58[b]	8.11
Dorsal fin rays	27.04	0.98	24.00	28.00	3.64	27.32[a]	3.09	26.76[b]	3.89
Radios dorsal fin	26.12	1.54	24.00	35.00	5.89	26.52[a]	7.07	25.72[b]	3.77
Anal fin rays	13.70	0.76	12.00	15.00	5.54	13.80[a]	5.86	13.60[a]	5.15
Radios anal fin	12.82	0.85	11.00	15.00	6.59	12.80[a]	6.31	12.84[a]	6.92

AC1: body depth at the first ray of the dorsal fin; AC2: body depth at the level of the first ray of the anal fin; AC3: body depth at the level of the first radius of the caudal fin; LC1: head width between the right and left point level flow side of the head; LC2: trunk thickness between the right and left at the level of most cranial point of the anal fin side; LC3:thick tail tween the right and left at the level of the last thorn on the back side; P1: body perimeter of the body at the level of first ray of the dorsal fin; P2: body perimeter at the level of the first radius of the anal fin; P3: body perimeter at the level of last ray of the dorsal fin. A,bWithin a row, means without a common superscript are different ($P < 0.05$).

Among the morphometric characters, the most used are the body weight (BW), total length (TL), standard length (SL) and head length (HL). The mean BW of

Vieja Colorada (Cichlasoma festae) from all data ranged from 55.8 g to 152.0 g with mean value of 90.45±18.2 g. The value of TL ranged between 12.5 and 25.0 cm with mean value of 18.27±1.75cm. The value of SL ranged between 9.8 and 19.0 cm with mean value of 14.14 ±1.58 cm, and the HL ranged between 4.4 and 6.5 cm with mean value of 5.35+0.48 cm. Cultured fish were larger than those coming from natural habitat, so weight and most morphometric variables showed higher mean values, except for LC3. The mean Pre-OL, AFL, LC2, LC3, AFR and RAF of the Vieja Colorada (Cichlasoma festae) from the two populations were not significantly different from each other.

The TL, HL, Pre-VL, AC1, AC2, P1, P2 and P3 showed a coefficient of variation lower that 10%; SL, Pre-DL and Pre-AL, PFL, PhBL, MaxBH, DFL, AC3 and LC1 showed a coefficient of variation between 10 and 20%, while the BW, Pre-OL, AFL, LC2 and LC3 showed coefficients of variation greater than 20%. The coefficients of variation of different morphometric characters were not significantly (P>0.05) different between populations, except for Pre-OL, Pre-DL, Pre-AL, AC3, LC2 and LC3.

The meristic characters showed mean values of 27.04 ± 1.0, 26.12 ± 1.5, 13.70 ± 0.8 and 12.82± 0.9 for DFR, RDF, AFR and RAF, respectively, with no significant difference (P> 0.05) among populations. The coefficients of variation were very low (<7%) and similar between populations.

Table 2. Frequency meristic characters from Vieja Colorada (Cichlasoma festae)

Count	Dorsal fin rays				Radios dorsal fin				Count	Anal fin rays				Radios anal fin			
	Cultured		Wild		Cultured		Wild			Cultured		Wild		Cultured		Wild	
	n	%	n	%	n	%	n	%		n	%	n	%	n	%	n	%
24							6	12	11					2	4		
25			8	16	10	20	14	14	12	2	4			16	32	22	44
26			10	20	24	48	18	18	13	16	32	26	52	22	44	16	32
27	28	56	18	36	16	32	12	12	14	22	44	18	36	10	20	12	24
28	22	44	14	24					15	10	20	6	12				

Dorsal fin rays (DFR) and radios dorsal fin (RDF) ranged from 24 to 28, presenting most of the 27 to 28 (82%) and 26-27 (70%) respectively. In anal fin rays (AFR) and radios dorsal fin (RDF) ranged from 11 to 15, presenting most

of the 13 to 14 (82%) and 12-13 (76%) respectively. Differences between cultured and wild were found (Table 3).

The descriptive statistics of the ratio of the standard length (SL) with other morphological characters are shown in Table 3.

Table 3. Descriptive statistics of the ratios between standard length and other morphometric characters (original data) from Vieja Colorada (Cichlasoma festae).

Ratio	All data					Cultured		Wild		P
	Mean	SD	Min	Max	CV%	Mean	SD	Mean	SD	
BW/SL	6.39	0.98	4.43	9.93	15.28	6.75	1.02	6.03	0.78	<0.000
TL/SL	1.30	0.08	1.11	1.51	6.24	1.29	0.06	1.31	0.09	0.156
HL/SL	0.38	0.05	0.26	0.53	11.91	0.37	0.04	0.39	0.05	0.008
Pre-OL/SL	0.16	0.03	0.08	0.26	21.42	0.15	0.04	0.16	0.03	0.158
Pre-DL/SL	0.38	0.04	0.19	0.51	11.68	0.38	0.03	0.39	0.05	0.391
Pre-VL/SL	0.41	0.04	0.29	0.55	9.26	0.41	0.04	0.42	0.04	0.559
Pre-AL/SL	0.65	0.08	0.26	0.84	11.88	0.62	0.08	0.68	0.06	<0.000
PFL/SL	0.57	0.08	0.39	0.97	13.68	0.55	0.06	0.60	0.08	0.002
PhBL/SL	0.24	0.03	0.17	0.33	13.59	0.23	0.03	0.25	0.03	0.014
MaxBH/SL	0.28	0.04	0.21	0.46	14.36	0.28	0.03	0.28	0.05	0.685
DFL/SL	0.43	0.04	0.33	0.53	9.70	0.42	0.04	0.43	0.04	0.709
AFL/SL	0.33	0.08	0.14	0.56	24.81	0.42	0.04	0.43	0.04	0.709
AC1/SL	0.39	0.03	0.28	0.48	8.19	0.38	0.03	0.40	0.03	0.036
AC2/SL	0.35	0.03	0.25	0.43	9.83	0.34	0.03	0.36	0.04	0.046
AC3/SL	0.14	0.02	0.11	0.19	11.51	0.14	0.01	0.14	0.02	0.092
LC1/SL	0.16	0.02	0.10	0.22	13.25	0.16	0.02	0.17	0.03	0.044
LC2/SL	0.11	0.03	0.06	0.27	23.27	0.10	0.03	0.12	0.02	0.004
LC3/SL	0.05	0.02	0.01	0.17	40.51	0.05	0.01	0.06	0.03	0.006
P1/SL	0.94	0.09	0.68	1.22	9.61	0.91	0.08	0.98	0.09	<0.000
P2/SL	0.81	0.08	0.66	1.07	9.65	0.78	0.06	0.84	0.09	<0.000
P3/SL	0.34	0.04	0.26	0.43	10.57	0.32	0.03	0.35	0.04	<0.000

body height; DFL: dorsal fin length; AFL: anal fin length; AC1: body depth at the first ray of the dorsal fin; AC2: body depth at the level of the first ray of the anal fin; AC3: body depth at the level of the first radius of the caudal fin; LC1: head width between the right and left point level flow side of the head; LC2: trunk thickness between the right and left at the level of most cranial point of the anal fin side; LC3: thick tail between the right and left at the level of the last thorn on the back side; P1: body perimeter of the body at the level of first ray of the dorsal fin; P2: body perimeter at the level of the first radius of the anal fin; P3: body perimeter at the level of last ray of the dorsal fin

The mean BW/SL ratio was 6.39±0.98, representing the HL 38% of SL, MaxBH 28%, body depth (AC1, AC2, AC3) from 39 to 14%, body thick (LC1, LC2, LC3) 16 to 5% and body perimeter (P1, P2, P3) 94 to 34%. The ratio TL, Pre-VL, Pre-VL, DFL, AC1, AC2, P1 and P2 with SL showed a coefficient of variation lower that 10%; ratios BW, HL, Pre-DL, Pre-AL, PFL, PhML, MaxBH, AC3, LC1 and P3 with SL showed a coefficient of variation between 10 and 20%, while, ratios Pre-OL, AFL, LC2 and LC3 showed coefficients of variation greater than 20%. In general, the coefficients of variation of the indices are slightly lower than those recorded in the corresponding morphological measurements.

Among populations, the BW/SL was significantly higher (P <0.05) in the cultured population, while relations HL/SL, Pre-AL/SL, PFL/SL, PhBL/SL, AC1/SL, AC2/SL, LC1/SL, LC2/SL, LC3/SL, P1/SL, P2/SL and P3/SL were significantly higher (P <0.05) in the wild population. Based on these relationships, wild fish were proportionately deeper at cranial level than cultured, without significative (P>0.05) differences at caudal level. Likewise, at cranial and caudal levels were proportionally wider. All this made the body perimeter/SL ratios, both at cranial and caudal levels significantly lower (P<0.05) in cultured fish.

The mean values (± SE) of the morphometric variables standardized by Elliot et al. (1995) are shown in Table 4. The mean values of BW, TL, SL and HL were 90.38+1.87 cm, 18.32 + 0.13 cm, 14.14 ± 0.16 cm and 5.36 ± 0.06 cm, respectively. The habitat had a significant effect (P <0.05) in some of the morphometric characters evaluated. BW, TL, SL, HL Pre-VL, DFL, AC1, AC2, AC3 and P2 were significantly higher (P <0.05) in cultured specimens. AFL, LC1 and P1 tended to be higher (P <0.1) in the cultured population.

Table 4. Mean values (+SE) of the morphometric variables adjusted (Elliot et al., 1995) from Vieja Colorada (Cichlasoma festae).

Character	Cultured		Wild		F	P
	Mean	S.E.	Mean	S.E.		
Body weight (g)	94.84	2.05	85.91	1.62	11.72	<0.001
Fulton condition factor, K	2.86	0.12	4.07	0.24	20.26	<0.001
Total length (cm)	18.52	0.12	18.08	0.15	5.64	0.019
Head length (cm)	5.46	0.07	5.26	0.06	5.33	0.023
Pre-orbital length (cm)	2.23	0.08	2.14	0.04	1.29	0.257
Pre-dorsal length (cm)	5.44	0.06	5.31	0.10	1.32	0.254
Pre-ventral length (cm)	6.00	0.07	5.67	0.05	16.30	<0.001
Pre-anal length (cm)	9.13	0.15	8.99	0.08	0.69	0.407
Pectoral fin length(cm)	8.08	0.11	7.97	0.12	0.39	0.535
Phariyngeal bone length (cm)	3.44	0.06	3.36	0.05	0.85	0.359
Maximum body height (cm)	3.99	0.07	3.83	0.08	2.38	0.126
Dorsal fin length (cm)	6.14	0.08	5.85	0.07	8.32	0.005
Anal fin length (cm)	4.77	0.15	4.40	0.13	3.52	0.064
AC1 (cm)	5.57	0.05	5.36	0.04	13.05	<0.001
AC2 (cm)	5.05	0.05	4.81	0.04	14.27	<0.001
AC3 (cm)	1.98	0.03	1.90	0.03	4.12	0.045
LC1 (cm)	2.36	0.03	2.27	0.04	3.02	0.086
LC2 (cm)	1.53	0.06	1.59	0.04	0.57	0.452
LC3 (cm)	0.69	0.02	0.74	0.04	1.12	0.292
P1 (cm)	13.40	0.14	13.12	0.08	2.93	0.090
P2 (cm)	11.55	0.07	11.20	0.08	10.68	0.001
P3 (cm)	4.74	0.06	4.72	0.05	0.07	0.793

AC1: body depth at the first ray of the dorsal fin; AC2: body depth at the level of the first ray of the anal fin; AC3: body depth at the level of the first radius of the caudal fin; LC1: head width between the right and left point level flow side of the head; LC2: trunk thickness between the right and left at the level of most cranial point of the anal fin side; LC3: thick tail tween the right and left at the level of the last thorn on the back side; P1: body perimeter of the body at the level of first ray of the dorsal fin; P2: body perimeter at the level of the first radius of the anal fin; P3: body perimeter at the level of last ray of the dorsal fin.

Fulton condition factor

The mean value of the condition factor K was 3.32 ± 0.9 (Table 1) for the original data set, with mean values of 3.01 and 3.62 for cultured and wild populations, respectively. The coefficient of variation was high (27.8%). Once the data were adjusted to SL (Elliot et al., 1995), the mean value of the condition factor K was 3.47 ± 0.15, with significantly higher values (P <0.001) in the wild that in the cultured population (Table 4).

Length-weight relationship

The parameter b of the fishes studied ranged from a minimum of 1.57 to a maximum of 2.46 with a mean value of 2.096 ± 0.078, with a slightly higher average value in cultured fish when compared with wild fish (2.21 vs. 1.97).

Relationships between morphometric characters

The morphometric relationships between numerous body parts of fish can be used to determine possible difference between separate unit stocks of the same species (King, 2007). Correlation coefficients of the morphometric and meristic characters to each other are shown in Table 5. Generally, all such correlations were positive for the two populations, but while some variables were strongly correlated, others were weakly so. The results reveal that the size effect was almost entirely eliminated in the populations during analysis as there were no significant correlations between TL and SL with most of the remaining parameters measured with the analyzed characters. The significant correlation coefficients ($P < 0.05$) were between 0.3 and 0.5, exceeding 0.6 on rare occasions. Meristic characters, except radios dorsal fin, are not related significantly ($P > 0.05$) with each other or with other morphometric characters.

Table 5. Correlation coefficients between the twenty seven morphometric and meristic parameters, and condition factor K of cultured (below the diagonal) and wild (above the diagonal) Vieja Colorada (*Cichlasoma festae*).

	1	2	3	4	5	6	7	8	9	19	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		**0.499**	**0.458**	**0.300**	0.21	**0.391**	**0.448**	**0.435**	**0.397**	**0.337**	0.259	0.259	-	**0.390**	**0.394**	**0.541**	**0.509**	**0.469**	-	**0.597**	**0.392**	**0.395**	0.125	-	0.189	0.168	-0.012
2	**0.349**		**0.687**	**0.310**	0.262	**0.295**	**0.415**	**0.431**	**0.310**	**0.401**	0.075	**0.438**	0.035	**0.604**	**0.456**	**0.389**	**0.412**	**0.381**	-	**0.465**	0.237	**0.36**	0.231	0.173	0.078	0.128	**-0.577**
3	**0.319**	**0.776**		0.237	0.225	**0.411**	**0.505**	**0.492**	**0.308**	**0.352**	0.162	**0.339**	-	**0.454**	**0.286**	**0.470**	0.186	**0.308**	-	**0.456**	0.208	**0.348**	0.051	0.021	-	-	**-0.873**
4	**0.387**	-	0.042		**0.565**	**0.282**	**0.341**	**0.386**	**0.306**	**0.453**	**0.421**	**0.536**	0.091	0.261	**0.318**	0.266	0.220	0.175	-	0.145	0.093	0.164	0.049	0.012	0.066	0.137	-0.110
5	0.247	-	-	**0.359**		**0.322**	0.236	0.260	0.276	0.274	**0.507**	**0.618**	0.108	0.243	0.082	0.276	-	-	-	0.060	**0.280**	**0.340**	0.053	0.001	0.099	0.189	-0.130
6	**0.484**	-	-	**0.512**	0.040		**0.474**	**0.422**	0.145	0.223	0.228	**0.405**	-	0.219	**0.348**	**0.328**	0.175	0.273	-	**0.373**	0.184	0.234	0.250	0.209	0.227	**0.320**	-0.215
7	**0.572**	-	**-**	**0.461**	**0.345**	**0.381**		**0.496**	0.064	0.108	**0.332**	**0.429**	0.051	0.199	0.179	0.158	0.245	**0.321**	-	**0.449**	0.231	**0.397**	0.219	0.171	0.152	0.155	**-0.338**
8	**0.359**	0.185	**-**	0.272	0.060	0.247	**0.334**		**0.340**	0.074	0.202	**0.381**	-	0.103	0.209	0.228	**0.415**	**0.283**	-	**0.372**	0.274	0.248	0.239	0.183	0.118	**0.311**	**-0.307**
9	**0.394**	-	-	**0.357**	0.182	**0.318**	**0.288**	0.213		**0.346**	0.070	0.137	-	0.147	0.045	**0.333**	**0.317**	0.149	-	0.249	0.048	0.111	0.058	-	0.176	0.153	-0.051
10	-	-	-	0.006	**0.430**	-	0.077	**-**	-		0.096	**0.356**	0.123	**0.341**	**0.318**	**0.478**	**0.325**	0.233	0.172	**0.328**	0.263	0.193	0.133	0.044	0.019	0.115	-0.191
11	0.266	0.181	-	0.250	0.136	**0.331**	0.236	-	0.200	0.190		**0.488**	0.204	0.214	0.203	0.143	0.092	0.054	-	0.153	0.133	**0.369**	-	**-**	-	0.09	-0.062
12	**0.313**	-	0.034	0.145	0.120	0.217	**0.320**	-	0.140	**0.412**	**0.601**		0.180	**0.462**	**0.372**	0.258	0.141	0.113	-	**0.362**	**0.354**	**0.451**	0.159	0.139	0.056	0.237	-0.269
13	-	**0.302**	0.039	0.040	0.095	**-**	-	**-**	-	**0.338**	0.009	0.009		0.156	0.045	-	0.084	-	-	0.151	0.249	0.077	0.103	0.080	0.040	0.153	0.116
14	**0.679**	**0.301**	-	**0.297**	0.181	**0.504**	**0.542**	**0.376**	**0.460**	-	0.258	**0.285**	-		**0.688**	**0.321**	0.271	0.277	0.001	**0.322**	**0.298**	0.236	-	-	0.058	0.071	**-0.344**
15	**0.390**	0.170	-	**0.355**	0.140	**0.328**	**0.349**	**0.377**	0.103	-	0.084	0.141	-	**0.535**		**0.362**	**0.446**	**0.524**	0.188	**0.299**	**0.286**	0.152	0.094	0.119	0.012	0.165	-0.154
16	**0.456**	0.025	**-**	0.150	0.205	0.080	**0.325**	0.255	0.216	-	**0.281**	**0.294**	-	**0.361**	0.237		**0.325**	**0.440**	**0.318**	**0.349**	**0.315**	0.262	0.004	-	**0.286**	**0.282**	-0.215
17	**0.528**	0.103	0.021	**0.452**	0.228	**0.333**	**0.449**	**0.308**	0.201	0.006	0.141	0.173	-	**0.377**	**0.360**	**0.411**		**0.511**	**0.292**	**0.393**	0.204	0.051	0.211	0.095	0.093	**0.309**	0.045
18	-	0.212	-	-	0.021	-	-	-	**-**	-	-	-	0.118	-	0.105	0.107	-		0.206	**0.315**	**0.382**	0.084	0.144	0.102	-	0.085	-0.139
19	0.192	-	0.014	-	-	0.105	0.011	-	-	0.089	0.163	0.217	0.250	0.178	0.087	0.024	0.217	0.205		-	0.014	-	0.060	0.008	0.121	0.227	0.216
20	**0.549**	**0.353**	0.188	0.239	0.065	0.262	**0.349**	0.240	0.185	-	0.136	0.239	0.081	**0.576**	**0.428**	0.124	**0.431**	0.030	**0.506**		**0.410**	**0.543**	**0.292**	0.221	0.177	0.168	-0.222
21	**0.472**	0.247	0.036	0.229	0.265	0.181	0.265	-	0.269	0.053	0.176	**0.328**	-	**0.441**	0.278	**0.302**	**0.308**	0.108	-	**0.317**		**0.374**	0.152	0.144	0.036	0.178	-0.056
22	**0.580**	0.018	-	0.219	-	**0.479**	**0.313**	0.234	0.219	-	0.176	0.256	-	**0.398**	0.159	**0.318**	**0.408**	-	0.172	**0.394**	**0.501**		0.118	0.115	0.197	0.141	-0.218
23	-	-	0.136	-	-	-	-	-	-	0.054	0.192	0.088	0.191	-	0.041	-	**-**	-	-	-	-	**-**		**0.943**	0.202	**0.443**	-0.035
24	-	0.241	**0.339**	-	-	-	-	**-**	-	**0.364**	**0.357**	**0.338**	**0.336**	-	-	0.104	-	-	0.010	-	0.101	-	**0.331**		0.192	**0.373**	-0.080
25	0.041	-	-	-	-	0.152	-	0.048	-	-	0.019	-	-	-	0.124	0.086	0.022	0.184	0.217	-	-	0.016	0.216	-		**0.748**	0.147
26	0.041	-	-	-	-	0.152	-	0.048	-	-	0.019	-	-	-	0.124	0.086	0.022	0.184	0.217	-	-	0.016	0.216	-	**1.000**		0.129
27	**0.309**	**-**	**-**	0.195	0.261	-	0.123	0.088	0.073	-	-	-	0.115	-	0.024	-	0.187	-	-	-	-	-	0.094	-	0.138	0.138	

1=weight; 2=total length; 3=standard length; 4=head length; 5= Pre-orbital length; 6=Pre-dorsal length; 7=Pre-ventral length; 8=Pre-anal length; 9=Pectoral fin length; 10=Pharyngeal bone length; 11=Maximum height body; 12= Dorsal fin length; 13=Anal fin length ; 14= body depth at the first ray of the dorsal fin; 15= body depth at the level of the first ray of the anal fin; 16= body depth at the level of the first radius of the caudal fin; 17=Head width between the right and left point level flow side of the head; 18=trunk thickness at the level of most cranial point of the anal fin side; 19=thick tail at the level of the last thorn on the back side; 20= body perimeter at the level of first ray of the dorsal fin; 21= body perimeter at the level of the first radius of the anal fin; 22= body perimeter atthe level of last ray of the dorsal fin; 23=Dorsal fin rays; 24=Radios dorsal fin; 25=Anal fin rays; 26=Radios anal fin; 27=condition factor Kdata in bold indicate significant differences; * 0.3>r<0.5; **0.5>r<0.7; *** 0.7>

Discriminant analysis

Four morphometric variables out of 23 were selected as predictors in the canonical discriminant analysis (Table 6). Wilks' Lambda indicated that the data were appropriate for discriminant analysis, whereas eigenvalue and canonical correlation pointed that the canonical function had very good discrimination ability.

Table 6 Canonical discriminant analysis results for morphometric variables

	Standardized canonical coefficients	Pooled Canoical structure
SL	0,99	0,64
Pre-VL	0,51	0,33
AC2	0,47	0,31
AFL	0,30	0,15
Wilks' Lambda	0,39	
Eigenvalue	1,54	
Canonical correlation	0,78	
Class means		
Cultured	1,23	
Wild	-1,23	

The Mahalanobis squared distance between the cultured and wild populations was 6.03 and F-test of the distance was highly significant ($P < 0.0001$). SL, followed at some distance by Pre-VL, AC2 and AFL, had the greater discriminating ability and the highest correlation value with the canonical discriminant function, according to the standardized canonical coefficients and the pooled within canonical structure, respectively. Fisher's linear discriminant functions are shown in Table 7. In the original classification matrices, 8 cases were misclassified in the cultured group and 4 cases were misclassified in the wild group. In cross-validated classification matrices, 9 cases were misclassified in the cultured group and 7 cases were misclassified in the savage group. As a result, 88.0 and 84.0% of the original grouped cases were classified correctly in the original and cross-validated classification matrices, respectively.

Table 7 Fisher's discriminant functions for morphometric variables

	Cultured	Wild
Constant	-441,77	-375,03
SL	19,77	17,80
Pre-VL	41,88	38,83
AC2	57,95	54,36
AFL	8,19	7,47

SL: Standard length; Pre-VL: Pre Ventral length; AC2: body depth at the level of the first ray of the anal fin AFL: Anal fin length.

Regarding meristic variables, the only RDF was selected as predictor and, despite the Wilks' Lambda statistical significance ($P < 0.01$), the eigenvalue and the canonical correlation were very low (0.09 and 0.29, respectively). The obtained Fisher's linear discriminant functions correctly classified 61 and 58% of the original grouped cases in the original and cross-validated classification matrices, respectively.

Discussion

Morphometric characters

According to Turan et al. (2006), the introduction and domestication of a fish species (especially those from the wild) leads to high adaptation to a wide range of geographical locations, which leads to phenotypic variations with respect to the pure stock (strains) of the brood stock. In order to know the ecological variation and to evaluate morphological differences between wild and cultured fish of the same species, different authors have used morphometric and meristic variables (Narvaez et al., 2005; Fagbuaro et al., 2015; Solomon et al., 2015) to quantify biological variation and identify and explain adaptive processes of different populations of the same species On the basis of the classification of Negi and Nautiyal (2002), of the morphological characters studies from Vieja Colorada (Cichlasoma festae), 12 characters were genetically controlled, 8 characters were intermediate and 7 characters were environmentally controlled. Twenty one characters have been studied in percentage of standard fish length from which seven characters were genetically controlled, nine characters were intermediate and five characters were environmentally controlled.

In the current study, it has been observed that the meristic counts did not change with increasing or decreasing body weight and length of the fish. Similar variations in meristic characters were reported in many fishes such as Nematalosa nasus (Al- Hassan, 1987), Pseudobagrus ichikawai (Watanabe, 1998), Pterophyllum scalare Bibi-Koshy et al., 2008), Garra gotyla gotyla (Gray) (Brraich and Akhter, 2015) This study recorded significant differences ($P<0.05$) between populations in eleven morphometric parameters, in agreement with Fagbuaro et al. (2005) and Solomon et al. (2015). Barriga-Sosa et al. (2004), after analyzing morphometric characters in natural and domesticated populations of Nile tilapia (Oreochromis niloticas), reported morphological differences among these populations. Likewise, Narvaez et al. (2005) found significant differences between the two populations (wild and cultured) of Oreochromis niloticas in northern Colombia; differences attributed to food, environmental conditions and the type of habitat (wild and cultured). However, in the present study, not all myristic characters registered showed significant differences between populations contrary the results obtained by Solomon et al (2005) in Clarias gariepinus. The discrepancy between results could be attributed to the characters studied in each work In the present study, TL/SL and DFL/SL ratios were not significantly ($P > 0.05$) different between cultured and wild specimens, in contrast to results obtained by El- Zaeen et al. (2012). While there is overlap between the two works in the differences between populations (cultured and wild) in the ratio between the standard length and depth and width of the body. These authors point out that the highest mean value of TL/SL in Nile tilapia (Oreochromis niloticas) was recorded by cultured population and differed significantly ($P<0.05$) from that of the wild population. Also, the mean value of HL/AC1 ratio was not significantly different between populations (wild and cultured), in contrast to the results offered by Narvaez et al. (2005) who observed that domesticated individuals were characterized to show sharpest heads than those of naturalized fish. Solomon et al. (2015) recorded significant differences in the ratio HL/SL in wild (23.7) and cultured (26.6) populations of C. gariepinus. Similarly, Vreven et al. (1998) and Barriga-Sosa et al. (2004) indicated that the biggest differences between wild and cultured populations were presented at the head. The value of this relationship

and other relationships between morphometric characters is closely linked to the species so it is not surprising that they can register differences between studies. Thus, Van der Bank et al. (1989) reported mean values from 0.29 to 0.34 for HL/SL and 0.31 to 0.45 for body deep/SL in fifteen cichlid fish species endemic to southern Africa, whereas in our study means the values for these ratios were 0.38 and 0.39, respectively. Brraich and Akter (2015) in Garra gotyla gotyla (Gray) recorded mean values of 0.27 and 0.18, respectively. According Vreven et al. (1998) the confinement of domesticated fish affects their growth rate, without allowing elongate the body, which would result in a higher K value. Contrary to this, in our work the value of K is higher in wild specimens.

Fulton condition factor (K)

Condition factor is a useful index for the monitoring of feeding intensity, age, and growth rates in fish (Oni et al., 1983). It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live.

The condition factor values of Vieja Colorada (Cichlasoma festae) from the current study (3.32) were comparable to those registered by Chukwuemeka et al. (2014) in Tilapia aurea, Tilapia galileae y Auchenoglanius occidentalis and lower than those reported by Anene (2005) in four cichlid fish (4.9). However, Fagbuaro et al. (2015) recorded significantly lower values (0.68) in Clarias gariepinus fish. The correlation coefficients between the factor K and the total length or standard length are negative (-0.488 and -0.774, and -0.557 and -0.873 for cultured and wild fish, respectively) and statistically significant ($P < 0.01$ and 0.001), indicating with increasing size of the fish that a shortened factor occurs. These results are consistent with those obtained in four Cichlid species by Anene (2005) who registered a significant and progressive decrease ($p < 0.05$) between the size range of 120 mm and 150 mm. Sasi and Berber (2012) recorded increases in condition factor until the age of 5 years (from 1.6 to 2.5) and a drop below.

In disagreement with Fagbuaro et al. (2015) the condition factor K was higher in wild population. This implies that the fish from the cultured population may not have been fed to the required level.

Length-weight relationship

In the present study, the length-weight relationship parameter b is lower than in many studies (Abdallah, 2002; Bayhan et al, 2008; Sasi and Berber, 2012) and close (2.27 to 2.46) to that obtained by Fagbuaro et al. (2015), although it is located in the range of values (1.51 to 3.49) indicated by Bok et al. (2011). This study shows that the fish from the both cultured and wild fish population have exhibited negative allometry, which does not maintain their specific body shape throughout their life. These results also denoted that both wild and cultured habitats do not provide enough food to maintain an isometric growth.

In contrast to the results obtained by Fagbuaro et al. (2015) (2.27 for farmed fish and 2.46 for wild fish), in the present study the parameter b was higher in the cultured population.

Correlation among morphometric variables

Out of twenty seven characters, two characters show high values of correlation coefficient and twenty five characters show moderate to low correlation coefficient (Table 5). In Vieja Colorada (Cichlasoma festae), BW was found to be most correlated part. In general, the correlation coefficients between morphological variables were slightly higher among wild fish, and clearly lower than those recorded by Brraich and Akhter (2015) in Garra gotyla gotyla. Chukwuemeka et al. (2014) recorded correlation coefficients between live weight and standard length of 0.76 to 0.94 in Tilapia galilaea, Tilapia aurea and Auchenoglanis occidentalis from Tagwai Lake (Nigeria). The variations observed in correlation coefficients of the morphometric and meristic data for wild and cultured Cichlasoma festae, aligned with the results obtained by Solomon et al. (2015), could be linked strongly to feeding pattern, environmental conditions, and genetic variability. Also, there is sufficient evidence to prove the influence of habitat in fish morphology (Turan et al., 2006).

Discriminant analysis

Canonical discriminant analysis demonstrated a clear influence of origin in the morphometric variables and a low effect in the meristic characters measured in the present work. The fact that only four morphometric variables were needed

to separate the two groups suggests that Fisher's linear discriminant could be useful to identify the origin of stocks on a commercial basis. However, Van der Banket et al. (1989) attribute less value to the morphologic variables than to meristic counts in the differentiation of populations of the same species. The meristic counts showed a very low variability and overlapped broadly showing no divergence among the populations, in agreement with several authors (Gacitúa et al., 2008; El-Zaeem et al., 2012; Solomon et al., 2015). These characters, due to their relative stability, cannot give the necessary variability of measurements which is essential for multivariate analysis and stock discrimination studies. Although the causes of morphological differences between populations are often quite difficult to explain, the morphometric differences between the cultured and wild Vieja Colorada (Cichlasoma festae) could have been linked to environmental factors, but also breeding over several years may have diluted the initial gene pool of the domesticated fish leading to genetic variation (translated to morphological differences) (Solomon et al., 2015).

Conclusions

The rearing system (cultured or wild) significantly influences most of the analyzed morphometric and meristic characteristics of two populations (wild and cultured) of Vieja Colorada (Cichlasoma festae). Twenty two morphometric and 4 meristic characters were used to test the hypothesis differentiation. Univariate analysis of variance showed significant differences for 21 standardized morphometric measurements out of 26 characters among the means of the wild and cultured populations tested. The condition factor values which were significantly different from each other, and showed that feeding could be improved in the farms. Both groups were accurately separated by linear discriminant functions that included only four morphometric measures. These results are of vital importance for the Ecuadorian population because they will allow to plan further breeding and conservation strategies for this native fish and improve productivity.

*4.*2. EFFECT OF FISHERIES SYSTEMS ON FLESH CHARACTERISTICS YIELD, FLESH PARAMETERS, AND PROXIMATE AND FATTY ACID COMPOSITION IN MUSCLE TISSUE OF WILD AND CULTURED VIEJA COLORADA (*CICHLASOMA FESTAE*) IN TROPICAL ECUADORIAN RIVER

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EFFECT OF FISHERIES SYSTEMS ON FLESH CHARACTERISTICS YIELD, FLESH PARAMETERS, AND PROXIMATE AND FATTY ACID COMPOSITION IN MUSCLE TISSUE OF WILD AND CULTURED VIEJA COLORADA (*CICHLASOMA FESTAE*) IN TROPICAL ECUADORIAN RIVER

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Abbreviations used: SFA (Saturated fatty acid); MUFA (Monounsaturated fatty acid); PUFA (Polyunsaturated fatty acid); DHA (Docosahexaenoic acid); EPA (Eicosapentaenoic acid); ALA (α-linolenic acid); WHC (Water holding capacity); BHT (Butylated hydroxytoluene); FAME Fatty acid methyl esters); FID (Flame ionization detector); IA (Index atherogenicity); IT (index thrombogenicity)

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Abstract

This study was conducted to determine the composition of cultured and wild *Cichlasoma festae* in Ecuador. The mean slaughter yield and dress-out were similar for cultured and wild specimens and the average fillet fat content for cultured fish was significantly higher compared to the wild fish. The pH, fillet color, drip loss and coked loss were similar between populations. Significant differences were found in protein, lipid and ash content in both studied populations. This study showed that saturated fatty acid (SFA) was higher than sum of monounsaturated (MUFA) and polyunsaturated fatty acid (PUFA) in both populations. Palmitic, oleic and linoleic acids had the maximum percentage of saturated and mono and poly unsaturated fatty acids respectively. In cultured and wild fish was also found to differ in the PUFA/SFA, docosahexaenoic acid (DHA)/eicosapentaenoic acid (EPA), n-3/n-6 ratios and atherogenicity (IA) and thrombogenicity (IT) indices. Minerals included calcium, phosphorous, potassium, magnesium, zinc, iron, cooper and manganese. There were significant differences in Ca, P, K, Mg, Zn and Fe. The production system (cultured or wild) influences significantly most of the analyzed characteristics of carcass and flesh of *Cichlasoma festae*. These results provide valued nutritional information of native species to produce sources of food with low-fat and high-protein, and safety food for the consumers in Ecuadorian country.

Keywords: flesh parameters; omega-3; fatty acid; proximate analysis; minerals.

Introduction

Nowadays, fish products freshness and quality has become the key strategic priority for the fish industry. Consumers are increasingly aware of fish benefits for human health, and always ask for high quality products. For their nutritional characteristics, fish is considered an excellent source of high quality protein, essential minerals and low-fat product. Among other properties fish is the best source of polyunsaturated long chain omega-3 fatty acids, which are beneficial to human health. Highlights include eicosapentaenoic acid (EPA, C20: 5) and docosahexaenoic acid (DHA, C22: 6) that are not synthesized in the human body but their inclusion in the human diet is essential (Valenzuela et al. 2011, Luczynska. et al., 2014). They both recognize the positive effect of consumption of fish and fish oils on human health. Numerous studies confirm the reduction of

the incidence of many diseases, including cardiovascular disease, psychiatric and mental illness (Saravanan et al., 2010).

Regarding minerals, fish meat is considered a source of calcium and phosphorus, as well as iron and copper (Izquierdo et al., 2001). Fishing in Ecuador has progressively increased. In 2011 fishery production was about 663,600 tonnes of which 391,700 tonnes were derived from capture fisheries and 308,900 tonnes from aquaculture. Aquaculture in Ecuador is a source of employment and foreign exchange for the country that contributes to poverty alleviation, food security and maintains the livelihoods (FAO 2014). The main species of fish that are caught on the coast and Ecuadorian Amazon are Vieja Colorada (Cichlasoma festae), Vieja Azul (Aequidens rivulatus), Bocachico (Prochilodus magdalenae), Dama (Brycon alburnus), Ratón (Leporinus ecuadoriensis), Huanchiche (Hoplias microlepis) and Dica (Lebiasina bimaculata) among others (FAO, 2014).

The increase in world population demanding high amount of fish protein makes it necessary to develop research to increase knowledge of systems and aquaculture products nutritionally (Naylor et al., 2000; FAO, 2008). According to Tveterås et al. (2012) it is estimated that about 3 billion people consume meat of fish and other marine organisms as the main source of protein. According to Gonzalez-Artola (2004) is important for farmers to know the differences between cultured and wild fish of different species; this could lead them to understand the chemical, physical, nutritional and sensorial profiles of the wild animal an try to reproduce it in their farmed products. However, few studies have been made of the nutritional composition of the species most consumed in Ecuador, as well as the different production systems (cultured and wild). Among them, it can be mentioned the ones from Cahu et al. (2004) and Alasalvar et al. (2002), which underline the differences in lipid levels, especially EPA, DHA and n-3 PUFAs according to the production system.

This study aims to evaluate the carcass and fillet characteristics, proximal and fatty acid composition and nutritional value in muscle tissue of native species Cichlasoma festae, species of high commercial value and high consumption of the local population, in different habitat in Ecuador: cultured and wild systems.

The results obtained will be valuable in designing sectorial policies and programs related to the health of the people of Ecuador. Furthermore, these data are of great interest to fisheries to establish conservation strategies and support the sustainable development of these native species.

Materials and methods

Study area

The study was conducted in three areas of the Babahoyo River and the fish farm center located in the Province Los Rios (Ecuador). The area has a tropical climate with an average temperature of 25 °C, an annual rainfall of 2400 mm and a relative humidity of 82%. The salinity of water, both in the river and the fish farm, does not exceed 0.1%, the pH was between 7.0 and 7.29, the range of temperature is 19.7ºC and 24.7ºC cultured fish, while the dissolved oxygen in the river and fish farm is between 6.8 and 8.9 mg/l, respectively. The conductivity values are about 145 Ms cm^{-1}

Collection of specimens, sampling and slaughter

One hundred matured fish samples (following the rules described by Frost and Kipling, 1980; Chávez-Lomelí et al., 1988; Konings, 1989), of Vieja Colorada (Cichlasoma festae) comprising of fifty individuals from natural habitat (wild population) and fifty from a cultured environment (private fish farms, cultured stock) were collected at dawn over the month of May 2016 with the help of standard fishing gears like cast and hand nets. Since male and female could not be differentiated morphologically, sexing of the sampled fish was not carried out. Specimen collection was performed weekly by purchasing representative samples of the two selected populations from local fishermen (wild fish) or fish farm (cultivated fish). Wild fishes were caught from three different locations within their natural geographic distributions in Babahoyo River (Provincia de los Rios, Ecuador). Cultured fishes were collected from fish farm. Just after catching, the fish specimens were kept in a glass flow through aquaria with continuous air and filled with 200 L of dechlorinated tap water, transported alive and housed in two masonry tanks (capacity of 500 L) (disolved oxygen = 6.20 ± 0.0 mg L−1, temperature = 20.5 ± 0.2 °C and pH = 5.6 ± 0.1). The fish rested for 48 h before the experiment, with fasting time of 24 h before stunning. On the

day of the experiment, the water in the tank was reduced by half; the fish were quickly caught with a net and transferred to a plastic box (100 L) and kept indoor. For stunning, the fish were placed at the same time in a mixture of 40 L of ice and 40 L of water (0.8 °C) until the apparent stunning (20 min) was over. After confirmation of death, the fish were identified, and liveweight and pH was performed.

Then, the collected fish were rapidly bagged, packed in an undistorted condition and stored at 0+2 ºC in chilly bins containing ice, and carefully brought to a laboratory in Facultad de Ciencias Pecuarias de la Escuela de Zootecnia de la Universidad Técnica Estatal de Quevedo (Ecuador) for further analysis and processing. Finally, the study was carried out according to Ecuadorian national recommendations for the management of fish, taking into considerations the rules on animal welfare.

pH

Muscle pH was determined after death (pH0), at 2 hours (pH2) and 12 hours (pH12) post-mortem by inserting a pH electrode (portable meat pHmetre, HI99163, Hanna Instruments Ltd, UK) into the Flesh Quality Cut; dorsal part of the fillet posterior to the head. The instrument was frequently calibrated using pH 4.01 and pH 7.00 buffers, and the electrode was also cleaned to obtain consistent results.

Cutting, filleting and meat colour

At the laboratory the fishes were kept in boxes with ice in cold stores at 2±1 °C, and flake ice was added to the boxes as required. Laboratory analyses started 24 h after death when rigor mortis had passed in most of the chilled fishes. Fish were dissected with a scalpel and scissors, and fins, scales, head, entrails, bones and flesh were removed and weighed. Head, guts, bones and flesh yield were calculated according to methodology propose by Rutten et al. (2004). After 45 minutes filleting, Surface colour measurements on right fillets were recorded at three positions using a portable colorimeter (Lutron RGB-1002 Chroma Meter) equipped with light source C and a 2º observed angle, calibrated to a white standard. The L*, a*, b* system colour profile was measured in all harvested fish. The colour variables calculate were L*, a* and b* where L*

describes lightness (+L* = white, -L* = black), a* red-green chromaticity (+a* = red, –a* = green) and b* yellow-blue chromaticity (+b* = yellow, -b* = blue) as recommended by CIE (1976). For each fillet, three measurements (along the length of the fillet) were done on the interior part of fillet, and values were combined to one mean value per fish for each of the three colour variables measured. Slaughter yield, dress-out and condition factor were calculated as:

Slaughter yield (%) = 100 x (gutted weight (g) / body weight (g))

Dress-out (%) = 100 × (round body mass (g) − gutted body mass (g)) / gutted body mass (g).

Condition factor = 100 x (round body mass (g)) / fork length3 (cm)

Drip and cooking losses

Two cubes of 10 mm × 10 mm × 20 mm were cut to determine drip loss of fresh muscle. The cubes were suspended on a pin inside a sample bottle (200 ml) taking care that the meat did not touch the sides of the bottle and stored for 24 h at 2±1 °C. The amount of drip measured between 24 h and 48 h post mortem, as the difference between the sample mass before and after, was expressed as a percentage of the starting mass:

Drip loss (%) = 100 x (final weight / initial weight)

The samples (approximately 30 g) were trimmed of external fat, weighed prior to cooking, placed in a polyethylene bag and immersed in a water bath (JP Selecta, Barcelona, España) at 80°C until the internal temperature of sample reached 70°C. The temperature was repeatedly monitored by a Type Kflexible high-temperature thermocouple (Hanna, Instruments, EE.UU) inserted into the geometric centre of each piece. Once the samples were cooled at room temperature (approximately 15ºC) for 40 min, they were re-weighed (after gently blotting on filter paper). Cooking loss percentage was calculated using the following equation:

Cooking loss (%) = 100 x (weight cooked meat / weight raw meat)

Proximate analyses

Muscle samples were homogenized using a 20.000 rpm grinder. Wet, crude protein, total fat and ash percents of fish muscle tissues were measured using standard methods of AOAC (AOAC, 1990). The crude protein content was measured by the block digestion method (UNE 55-020), ashing was done at 550 °C for 24 h (ISO R- 936), and the moisture content was determined by drying at 102 °C for 24 h (ISO R- 1442). Fat percentage was measured according to the Soxhlet method (ISO R-1443) using a Foss Tecator AB Soxtec 2050. Analyses were determined in duplicate, according to the the mean value of two determinations and expressed per 100 g muscle.

Fatty acid analysis

Skinned and deboned muscle from individual fish was blended into homogeneous flesh and total lipid extracted from 1g portions by homogenizing in 20 volumes of chloroform/methanol (2:1, v/v) in an Ultra-Turrax tissue disrupter. Aliquots of the lipids extracted were converted to fatty acid methyl esters (FAME) according to the procedure described by Chistie (1993). FAMES were separated and identified on GC Perkin Elmer Clarus 500 gas chromatograph with a flame ionization detector (FID) equipped with a TR-FAME capillary column (30 m x 0.25 mm i.d., 0.25 μm film thickness, Shinwa Inc.), using helium as a carrier gas at a flow rate of 0.5 ml/min. The injection and detector were maintained at 250 and 260 °C, respectively.

Theoven temperature was programmed at 100 °C, followed by an increase of 2 °C/min to 220 °C, with a final hold time of 20 min. Individual fatty acids were identified by comparing their retention times with those of a standard fatty acid mix Sulpeco 37 (Sigma Chemical Co. Ltd., Poole, UK). Nonadecanoic acid methyl ester (19:0 ME) was used as an internal standard. Individual fatty acids (FAS) were expressed as a percentage of total fatty acids identified and mg/g muscle tissue of fish, and grouped as follows: saturated fatty acid (SFA), monounsaturated (MUFA), polyunsaturated fatty acid (PUFA), ω6 and ω3. The PUFA/SFA, DHA/EPA, ω6/ω3, atherogenicity (IA) and thrombogenicity (IT) indices were also calculated. IA: indicating the relationship between the sum of the main saturated fatty ac-ids and that of the main classes of unsaturated, the former being considered pro-atherogenic (favoring the adhesion of lipids to cells

of the immunological and circulatory system), and the latter anti atherogenic (inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, there- by preventing the appearance of micro- and macro- coronary diseases). IT: showing the tendency to form clots in the blood vessels.

IA and IT indices were calculated by using the Ulbricht & Southgate (1991) equations.

$$IA = [(C12:0) + (4 \times C14:0) + (C16:0)] / [(PUFA\ \omega6 \text{ and } \omega3) + MUFA)]$$

$$IT = [(C14:0) + (C16:0) + (C18:0)] / [(0.5 \times MUFA) + (0.5 \times \omega6) + (3 \times \omega3) + (\omega3 / \omega6]$$

Trace mineral analysis

Approximately 1 g of fish flesh was subjected to the wet mineralisation by Kjeldahl method using a mixture of nitric and sulphuric acid (2:1, w/w) according to Alasalvar et al. (2002). Mineral contents were determined by plasma absorption spectrometer using a 200-DV (Perkin-Elmer, Waltham, EE.UU). The following elements were measured: potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), iron (Fe), zinc (Zn) y copper (Cu). Analyses were determined in duplicate, according to the mean value of two determinations and expressed in mg per 100 g of meat.

Statistical analysis

The data were statistically analysed by using SPSS 15, to compare the effect of the production system (wild and cultured). Statistical treatment of the data was done by calculating means and standard deviations. In addition, analysis of variance (ANOVA) was applied to determine possible significant differences for each parameter evaluated. Differences were considered statistically significant at $P < 0.05$.

Results

Biometric and yield parameters

Mean live weight, total length and condition factor of the specimens under study were 90.45+18.16 g, 18.27+1.75 cm and 3.32+0.92, respectively. The mean body weight, total length and condition factor of the cultured fish were 101.84 g, 19.40 cm and 3.01, respectively, whereas the mean weight, total length and condition factor of the wild fish were 79.06 g, 17.14 cm and 3.62, respectively.

Table 1 shows the body yield of Vieja Colorada (Cichlasoma festae) under two production systems. The coefficient of variation (data not show) ranged from 12.66% for flesh to 39.97% for guts, with mean values of 14.83% and 15.60% for head and skin + bones, respectively. One way ANOVA showed differences ($P<0.05$) among head, skin + bones and flesh percentages of cultured and wild fish samples. The percentage of head was significantly ($P<0.05$) higher in wild fish, while the percentages of skin + bones and flesh were higher in cultured fish. However, there were no significant ($P>0.05$) differences among guts percentage, slaughter yield and dress-out of studied samples. The edible portion represents 29.2% of fish weight, higher in cultured compared to wild.

Table 1 Least square means (+standard error) of head, guts, skin + bones, and flesh percentages (of total body weight), slaughter yield and dress-out in carcasses from Vieja Colorada (Cichlasoma festae, Boulenger, 1899) catched in Ecuador.

Variables	Mean (±SE) (n=100)	System	
		Cultured (n=50)	Wild (n=50)
Head %	38.75 ± 5.75	36.06 ± 0.69[a]	41.44 ± 0.72[b]
Guts %	4.60 ± 1.84	4.48 ± 0.29[a]	4.72 ± 0.22[a]
Skin + bones %	29.94 ± 4.67	31.09 ± 0.59[a]	28.79 ± 0.67[b]
Fresh %	29.19 ± 3.69	30.66 ± 0.45[a]	27.72 ± 0.49[b]
Slaughter yield, %	95.39±0.18	95.52±0.29 [a]	95.28±0.22 [b]
Dress-out, %	4.86±0.19	4.74±0.32 [a]	4.98±0.24 [a]

a,b Within a row, means without a common superscript are different ($P < 0.05$)

Flesh quality

The flesh quality characteristics of Vieja Colorada (Cichlasoma festae) are shown in Table 2. The coefficient of variation does not exceed 3% at pH values, it was about 10% in L*, 21% by cooking loss, 35% for drip loss and exceeded 45% in a* and b* (data not show).The pH post-mortem is the main factor which influences the quality of meat (Huss, 1995). In the first 12 hours postmortem, the pH dropped 6.02%, 5.47% and 6.69% in the total population, cultured and wild fish, respectively. This fall took place mainly in the first 2 hours postmortem (5.87%, 5.75% and 6.0%, respectively). Chromatic variables (L*, a*, b*), drip loss and cooking loss ranged from 41.8 to 71.8, from 1.35 to 9.91, from -2.44 to 11.34, from 1.09 to 4.81 and from 19.44 to 47.27, respectively. L*, a*, b* values indicate a pale meat with high L* value (have a tendency to white), low a* value (have a tendency to red) and low b* value (have a tendency to yellow). None of the variables showed significant differences (P > 0.05) among populations.

Table 2. Flesh quality characteristics (±standard error) of fillet from Vieja Colorada (Cichlasoma festae, Boulenger, 1899) catched in Ecuador.

Variables	Mean (±SE) (n=100)	System	
		Cultured (n=50)	Wild (n=50)
$ph_{0\ hours}$	7.15 ± 0.01	7.13 ± 0.02[a]	7.17 ± 0.03[a]
$pH_{2\ hours}$	6.73 ± 0.02	6.72 ± 0.02[a]	6.74 ± 0.03[a]
$pH_{12\ hours}$	6.72 ± 0.02	6.74 ± 0.03[a]	6.69 ± 0.03[a]
L*	54.52 ± 0.56	53.77 ± 0.67[a]	55.27 ± 0.91[a]
a*	4.51 ± 0.22	4.52 ± 0.32[a]	4.50 ± 0.29[a]
b*	5.93 ± 0.27	5.71 ± 0.42[a]	6.15 ± 0.34[a]
Drip loss %	2.70 ± 0.09	2.75 ± 0.13[a]	2.65 ± 0.12[a]
Cooking loss %	30.76 ± 0.64	30.87 ± 0.96 [a]	30.69 ± 0.85[a]

pH0 = pH at slaughter; pH2 = pH at 2 hours postmortem; pH12 = pH at 12 hours postmortem; L*, a* and b* = instrumental parameters color (CIE L*, a*, b)

Proximate analysis

The proximate composition of fish is affected by a diversity of factors such as: size, temperature, salinity, production system and feeding among other (Gonzalez-Artola, 2004). The results of proximate analysis of muscle tissue of Vieja Colorada (C. festae) samples are shown in Table 3.10. The cultured fish had higher (P < 0.05) crude protein, total fat and ash percentages compared to

wild specimens. There was no significant difference of wet in muscles between cultured fish with wild fish.

Table 3 Averages of wet, crude protein, total fat and ash percents (±standard error) in muscle tissue of cultured and wild Vieja Colorada (C. festae) collected from farm and at different areas of Babahoyo River in Los Rios province (Ecuador)

Variables	Mean (±SE) (n=100)	System	
		Farmed (n=50)	Wild (n=50)
Wet %	79,06 ± 0.21	78.84 ± 0.34[a]	79.27 ± 0.26[a]
Ash %	1,36 ± 0.01	1.42 ± 0.01[a]	1.29 ± 0.01[b]
Fat %	1,99 ± 0.01	2.03 ± 0.01[a]	1.96 ± 0.02[b]
Protein %	17,33± 0.18	17.86 + 0.27[a]	16.80 ± 0.21[b]

[a,b] Within a row, means without a common superscript are different (P < 0.05).

Fatty acid analysis

The fatty acid profiles of cultured and wild Vieja Colorada (C. festae) are listed in Table 5. In the present study, more abundant saturated fatty acids were palmitic (27.91+0.26%), stearic (9.0+0.09%) and myristic (7.12+0.17%) fatty acids. Monounsaturated oleic acid was the most abundant (19.74+0.30%) fatty acid in fish muscle samples, and linoleic acid was the most abundant (8.19+0.16%) polyunsaturated fatty acid. Muscle tissue of Vieja Colorada (C. festae) included 55.7% saturated, 21.2% monounsaturated and 23.2% polyunsaturated fatty acids.

In the present study, there were significant differences (P<0.05) in the content of most of the fatty acids analyzed between cultured and wild fish except for caprylic, lauric, palmitic, SFA, DHA and arachidonic contents which were similar (P>0.05) between systems.

Table 4 Mean weight (±standard error) and percent of fatty acids in muscle tissue of cultured and wild Vieja Colorada (C. festae)

Fatty acid and indices		All data (n=100)	Cultured(n=50)	System Wild(n=50)
C6:0, Caproic	mg/g	0.38± 0.16	0.46 ± 0.02	0.29 ± 0.01
	%	0.036±0.001	0.042±0.02	0.030±0.001
C8:0, Caprylic	mg/g	1.52 ± 0.31	1.55± 0.05	1.49 ± 0.03
	%	0,147±0.003	0,143±0.005	0,151±0.003
C10:0, Capric	mg/g	2.53 ±0.71	2.12 ±0.10	2.94 ± 0.05
		0,247±0.007	0,197±0.010	0,297±0.006
C12:0, Lauric	mg/g	19.04 + 3.59	18.82 ±0.20	19.26 + 0.68
	%	1,844±0.037	1,747±0.021	1,942±0.69
C14:0, Myristic	mg/g	79.19 ± 1.50	66.06 ± 0.99a	92.32 + 1.18
	%	7,717±0.172	6,129±0.099a	9,305±0.24
C15:0, Pentadecanoic	mg/g	17.75 ± 0.22	16.44 ± 0.19a	19.07 ± 0.31
	%	1,722±0.026	1,523±0.016a	1,921±0.031
C16:0, Palmitic	mg/g	289.21 ± 3.10	289.89 ± 3.44a	288.53 ± 5.19
	%	27,907±0.256	26,838±0.250a	28,975±0.397
C18:0, Stearic	mg/g	93.55 ±1.23	103.57± 1.08	83.53 ± 1.03
	%	9,003±0.086	9,596±0.087a	8,409+0.091
C20:0, Arachidic	mg/g	17.34 ±0.16	17.72 + 0.26a	16.97 ± 0.17
	%	1,677±0.016	1,644±0.026a	1,711±0.019
SFA	mg/g	577.15± 3.34	573.17 ± 3.72a	581.12 ± 5.54
	%	55,782±0.321	53,104±0.215a	58,460±0.296
C16:1, Palmitoleic	mg/g	34.23 ± 0.57	30.19 ± 0.61a	38.27 ±0.54
	%	3,327±0.065	2,798±0.055a	3,855±0.053
C18:1*n*-9 Oleic	mg/g	205.65 ± 4.04	244.15 ±2.39a	167.15 ±1.49
	%	19,735±0.301	22,617±0.182a	16,854±0.171
MUFA	mg/g	219.22 ± 1.94	274.35 ± 4.42a	205.43 ± 3.89
	%	23,062±0.265	25,415±0.185a	20,709±0.180
C18:2*n*-6 Linoleic (	mg/g	85.25 ± 1.87	100.38 ± 1.77a	70.12 ± 1.44
	%	8,187±0.155	9,307±0.163a	7,066±0.145
C18:3*n*-3, Linolenic (	mg/g	32.29 + 0.32	31.59 ± 0.45a	33.01 ± 0.43
	%	3,127±0.036	2,929±0.042a	3,326±0.044
C20:5(ω *n*-3 Eicosapentaenoic (EPA)	mg/g	21.24 ± 0.31	19.58 ± 0.33a	22.89 ± 0.42
	%	2,061±0.036	1,815±0.030a	2,307±0.043
C22:6(DHA) *n*(-3, Docoxahexaenoic	mg/g	46.03 ± 0.93	45.15 ± 1.56a	46.91 ±1.01
	%	4,453±0.090	4,178±0.139a	4,728±0.102
C20:4 *n*-6, Arachidonic (	mg/g	34.41± 0.34	35.05± 0.32a	33.76 ± 0.59
	%	3,328±0.036	3,253±0.036a	3,403±0.061

PUFA	mg/g	239.88 ± 3.7	231.75 ± 3.01a	206.69 ±2.03
	%	21,156±0.145	21,481±0.204a	20,831±0.198
PUFA/SFA	mg/g	0.38 ±0.01	0.41 ±0.01a	0.36 ±0.01
DHA/EPA	%	2.20 ±0.05	2.33 ±0.01a	2.08 + 0.01
ω3		0.858±0.018	0.717±0.015a	0.998±0.017
Atherogenicity index		1.390±0.028	1.134±0.012a	1.647±0.022
Thrombogenicity index		0.7880±.009	0.739±0.008a	0.838±0.013

Trace mineral analysis

Table 5 shows the trace mineral composition of the meat of cultured and wild C. festae. P, K and Ca were predominant elements among 8 minerals analysed and constituted 95.3% and 95.4% of total trace minerals content in cultured and wild C. festae, respectively. P, Ca, Mg were higher ($P < 0.05$) in cultured fish compared with wild fish. However, the content of K, Fe and Zn were lower in cultured fish. There were no-significant differences ($P > 0.05$) in Cu and Mn. According to Alasalvar et al. (2002) the concentration of trace minerals in fish is influenced by a numerous factors such as seasonal and biological differences, food source and environment.

Table 5 Mineral contents (±standard error) of fillet from cultured and wild Vieja Colorada (C. festae)

Variables	Mean (+ SE) (n=100)	System	
		Farmed (n=50)	Wild (n=50)
P	156.23 ± 15.85	166.39 ± 1.52 [a]	146.07 ± 1.84[b]
K	101.05 ± 8.85	94.28 ± 0.94[a]	107.81 ± 0.94[b]
Ca	189.05 ± 23.06	193.15 ± 3.61[a]	184.95 ± 2.63[b]
Mg	14.53 ± 2.03	16.26 ± 0.17[a]	12.80 ± 0.12[b]
Cu	0.233 ± 0.03	0.23 ± 0.004[a]	0.24 ± 0.002[a]
Fe	2.54 ± 0.52	2.08 ± 0.03[a]	2.99 ± 0.04[b]
Zn	4.05 ± 1.64	3.24 ± 0.19[a]	4.86 ± 0.20[b]
Mn	0.15 ± 0.03	0.15 ± 0.004[a]	0.16 ± 0.004[a]

Discussion

This study investigated the performance, flesh quality, fatty acids profile and trace minerals of native species C. festae reared in different habitat: cultured and wild. The results are important since they provide valuable nutritional information in order to produce sources of low-fat and high-protein food.

According to Jabeen et al. (2011) results will also offer important knowledge to scientists interested in finest quality, flavour, colour, odour, texture of food and safety for the consumers in Ecuadorian country.

Yield parameters of C. festae

The skeletal muscle (fillet) is the major part of the edible portion of fish. Fillet yield is the ratio between fillet weight and carcass weight and is a measure of the edible part of the body. Fillet yield depends on the species, sex and size, and on the structural anatomy of the fish. Fish with smaller head and frames relative to their musculature gives a higher fillet yield than fish with large head and frames. In cultured fish, yields can also be affected by farming conditions (feeding, water temperature, type of pond, and so on). The fillet yield for farmed species was found range from 40% to over 70% (Rørå et al. 2001). From commercially farmed fish species, tilapia (Oreochromis sp.) presents the lowest fillet yield (33%) as compared to salmon (Salmo salar) (>50%), channel catfish (Ictalurus punctatis) (>38%), and striped bass (Morone saxatilis) (>40%). Fillet yield of C. festae was similar to the 32% reported by Neto et al. (2012) in Pacu and Tambaqui fish and quite lower than those obtained by Sulieman and Keji (2011) for Nile Tilapia (Oreochromis niloticus), which reported values higher in farmed fish than in wild fish (37.1 and 32.2 respectively). Based on production systems the flesh percentage was higher in cultured fish (30.7% vs. 27.7%). The differences in fillet yield between wild and cultured fish can be attributed mainly to the slaughter weight and to food. However, Intarak et al. (2015) indicated that dress-out and fillet percentage did not change with slaughter weight. On the contrary, the study has achieved higher values than the ones observed by Simões et al. (2007) which reported a flesh yield (with skin) of 21.63% for Chitralada tilapia. In addition, it is known that the yield of different part of body in these species is linked to factors inherent to cichlids such as the anatomical body shape, head size and final weight (Rojas-Runjaic et al., 2011). Furthermore, Rutten et al. (2004) observed that the yield of tilapias depends on several factors such as body weight, sexual and physical condition, morphometric characteristics, processing techniques, efficiency of fish cutter, methods filleting, and presentation to consumers.

As expected, dress-out in the Vieja Colorada (C. festae) was much lower than in commercial species such as Atlantic salmon (Salmo salar L.). Thus, Johnsen et al. (2011) reported mean values of 10-12%.

Flesh quality

According to Huss (1995) pH post-mortem is the most important factor which influences the texture of meat; minor changes in pH impact dramatically the connective tissue properties that directly modify water-holding capacity (WHC) and drip losses. Marked muscle pH decrease within the first day after death, is caused by depletion of glycogen which is transformed in anaerobic conditions into lactic acid (Acerete et al. 2009). pH could be considered as an appropriate index of quality control of fish meat (Selmi and Sadok, 2008). Actually, living animals have a neutral pH of 7.0 to 7.2 in the muscle which decreases to 6.0 or below postmortem (Jaturasitha, 2007), in agreement with results obtained in the present study. Furthermore, the pH initial values were similar to those recorded by Bordarías and Sánchez-Alonso (2011) and Baygar et al. (2012) which reported pH_0 values of 7.13 and 7.17 respectively.

The drop in pH within 12 hours after death observed in our study agrees with the results obtained by Roth et al. (2009) who reported that muscle pH displayed a rapid decline in muscle pH during the first 12 h post mortem, between 12 and 24 hours postmortem decline is less pronounced and from 24 hours postmortem pH showed no significant variations indicating that the fish were reaching its end pH. Robb et al. (2000) recorded a rapid drop in pH after death in rainbow trout, although anaesthetized fish showed a much slower rate of fall in pH than that observed in electro-stimulated fish. Similarly, Roth et al. (2009) in a research based on Atlantic almon subjected to various stunning methods in combination with pre-slaughter conditions, indicated that fish displayed a rapid decline in muscle pH during the first 12 h post mortem. Also, other authors as Intarak et al. (2015) recorded pH declines in the first hours post-mortem, and Robb (1988) specified that within 1.5 h post- mortem, the muscle pH declined significantly ($P < 0.005$) from 6.90 ± 0.20 to 6.66 ± 0.11. The pH ultimate is within suitable values for human consumption (Scherer et al., 2006).

In this study just no significant differences (P > 0.05) were obtained in pH0, pH2 and pH12 among populations (Table). pH_{12} showed no evidence of pre-slaughter stress (6.75 and 6.69 in cultured and wild fish, respectively).

The values for drip losses and cooking losses were not significantly different between systems (Table 3.9), although they were higher than those found by Wangtueai and Vichasilp (2015) who reported, in Nile tilapia, cooking and drip losses values fluctuating between 17.78% - 26.37% and 0.7 - 3.95%, respectively. Intarak et al. (2015), in Punga Fish (Pangasius bocourti Sauvage), reported values of 4.88% to 2.88% for drip loss, with significant decreases with increasing liveweight. Roth et al. (2006) recorded drip losses <2% and> 5.5% in muscle tissue from rested and stressed fish, respectively, reflecting the best practices in the slaughter of fish in our study. In a later work, Roth et al. (2009) reported values ranging between 0.76 to 1.3% in Atlantic salmon.

Meat colour, an important treatment in aquaculture, was not affected by the system (cultured and wild). L*, a* and b* value indicate a pale meat. The results of our study were greater that Lima et al. (2015) in rainbow trout who reported value of L* 47.53 and 52.77 respectively. Roth et al. (2006, 2009) reported values ranging between 53.4 to 58.4 and 45 to 51 for L* in Atlantic salmon, respectively. As expected, a* and b* values registered in these studies (25.9-27.6 and 25.5-27.2, respectively) were much higher than those recorded in our study.

Proximate composition

The chemical composition of fish varies greatly from one species and one individual to another depending on age, sex, environment and season. The normal variation between the constituents in fish are: 66-81% for wet, 16-21% for protein, 0.2-25% for fat and 1.2-1.5% for ash (Chandrashetkar and Desthale, 1993).

Proximate analysis of muscle tissue has been studied in some marine and cultured fish especially correlated with fish nutrition. In particular, whole body fat is directly related to dietary fat content. While fish body composition appears to be largely influenced by feed composition, an increase in other parameters such as fish size, sexual maturation, temperature, exercise, among others, also

results in enhanced adipose deposition and decreases water content in the fish body (Shearer, 1994).

Noted to protein and ash content do not vary as often as lipid, since it is not affected by diet, but mainly is determined by the species type and genetic characteristics (Morris, 2001). Analytical results confirmed the higher lipid content in cultured fish compared to wild ones. The differences in composition between wild and cultured fish can be mainly attributed to the differences in the amount and food composition among systems.

In a study in Turkey on proximate composition of cultured O. mykiss (Mashaii et al., 2012), the protein (17.4-17.9%) and ash (1.38-1.59%) contents are very similar to the results of the present study, while the moisture (75.2-76.9%) and total fat (2.48-4.88%) contents are lower and higher, respectively. In Punga Fish (Pangasius bocourti Sauvage), Intarak et al. (2015) offered values of 78-79% for wet, 20-21% for protein and 1.0-1.6% for fat, outlining a significant increase in fat percentage with increasing liveweight. In line with these studies the results offered by Michelato et al. (2016) in Nile tilapia are placed. In general, the wet contents in the muscle fish of this study were within the range reported by Jabeen et al. (2001) and Filho et al. (2010). Fat content showed significantly differences between rearing systems and this variation in the total fat content was similar to the conclusions of other authors (Jabeen et al. 2011; Gonzalez-Artola, 2004). Fish is often classified on the basis of their fat content into lean fish (fat less than 2%), low fat fish (fat 2-4%), medium fat fish (fat 4-8%) and high fat fish (fat more 8%) (Ackman, 1990; Gonzalez-Artola, 2004). Based on this classification, C. festae is considered a lean fish (Table 3) such as cod and yellow perch. In agreement with Johnston et al. (2006) in Atlantic salmon, the total lipid content of the muscle was higher in cultured than wild fish.

In this study, protein of 17.33% wet weight was similar than protein levels for Carp (16% wet weight; FAO, 2008) but lower within the range of 18.64-22.7% and 18.4- 20.8% reported for the Cichlidae family by Sulieman and James (2011) and Perea et al. (2008), respectively. According to Hernandez and Aguilera (2012) ash content (1.36% wet weight) observed in this study was located within the ranges reported and was significantly different between systems.

Fatty acid

Fatty acids are the main organic component of fish, and attract the attention of consumers due to the importance in animal and human health. Fatty acids are divided in saturated and unsaturated fatty acids. These latter ones have been positively related to human health, in particular n-3 polyunsaturated fatty acids (Gonzalez-Artola, 2004; Hooper et al. 2004; Simopoulus, 2002). This way, American Heart Association (2002) and Hooper et al. (2004) confirmed that consumption of fish is related to lower risk of cardiovascular diseases and play a vital role in alleviating type-2 diabetes, inflammatory ailments and autoimmune disorder.

The composition of a particular species often appears to vary from one fishing ground to another and from season to season but the basic causes of change in composition are usually a variation in the amount and quality of food that the fish eats and the amount of movement it makes. Different patterns of fatty acid profiles were observed in this study among rearing system (Table 4). These results are not surprising since flesh quality appears to be under the strong influence of feed composition and feed amount, and therefore changes in the diet of a fish can result in a significant change in its fatty acid constituents. Caproic (C6:0), capric (C10:0), myristic (C14:0), pentadecanoic (C15:0), stearic (C18:0) and arachidic (C20:0) were significantly different between systems but no significant differences were found for total SFAs. This variation is in concordance with Aggelousis and Lazos (1991) and Schlectriem et al. (2007). In agreement with these authors, palmitic acid was the most important between saturated fatty acids, while oleic acid was the main fatty acid between the monounsaturated. In ω3 family fatty acids, EPA and DHA were the most important as indicated by Romero et al. (2000) and Mashaii et al. (2012). In agreement with Alasalvar et al. (2011), the oleic content was higher in cultured fish.

The higher amount of oleic acid in farmed sea bass and sea bream has been established to arise from its dominance in the commercial feed (Grigorakis et al., 2002). Note that arachidonic acid (C20:0) content was higher in cultured fish ($P < 0.05$) and this acid is precursor for prostaglandin and thromboxane biosynthesis aiding the blood clotting process during wound healing (Jabeen et

al., 2011). Linoleic acid (C18:2n-6) was the dominating polyunsaturated fatty acids (PUFAs) according to results found by Jabeen et al. (2011) for Cyprinus carpio, Labeo rohita and Orechromis mossambicus in Indus River (Pakistan). Linoleic acid values were different ($P<0.05$) among systems, being higher in cultured system. Similar results were found by Alasalvar et al. (2002) who related that certain amount of linoleic is linked to the feed ingredient. The presence of docoxahexaenoic (DHA) and eicosapentaenoic (EPA) suggest that C. festae could have a therapeutic effect to alleviate muscle pain and inflammation. According to Leaf and Webber (1988), DHA and EPA are key components for a healthy diet in humans. Although in this study DHA and EPA values were low (Table 3.11), it is important to highlight that, contrary to expectations, wild fish had higher EPA content (22.89mg/g). Finally, suitable choice of dietary lipid in cultured fish will allow improve the fatty acids profile, especially in n- 3 PUFAs. It has been observed that the pattern of fatty acids in fish vary mainly with what the fish eats, but other factors may influence such as size, reproductive status and location amongst others (Alasalvar et al., 2002; Saito et al., 1999).

In our study, the content of the saturated fatty acids was higher than that of unsaturated fatty acids, in agreement with Romero et al. (2000) who indicated that an analysis of fatty acids composition of 7 marine fish species in Easter Island revealed the highest saturated fatty acids (35.1 - 54 %) followed by the polyunsaturated fatty acids (22 - 42.5 %). In contrast, Schlectriem et al. (2007) in Atlantic salmon and Celik et al. (2008) and Mashaii et al. (2012) in two studies of muscle tissue of cultured O. mykiss in Turkey showed higher content of unsaturated acids. Higher amounts of saturated fatty acids in the present study might be assumed as a disadvantage of these fish.

The n-3/n-6 ratio in this study (0.86+0.02) was similar to that found by Hoseini et al. (2013) in farmed Big head carp (Hypophthalmichthys nobilis) and Grass carp (Ctenopharyngodon idella). An increase in the human dietary of n-3/n-6 fatty acid ratio is essential in the diet and nutritionists believe that this ratio should be 0.1-0.2 and consider higher ratios (>0.2) more beneficial to human health (FAO/WHO 1994). Simopoulos (2008) suggested that the n-3/n-6 ratio should be kept between 1:1 and 1:4. Amount of n-3/n-6 in cultured fish was

0.72±0.01 and in wild fish 0.99±0.02, there was significant difference between two rearing systems ($P < 0.05$), in agreement with Hoseini et al. (2013). Wild fish probably ingests higher rate of natural foods containing more EPA and DHA.

Atherogenicity (IA) and thrombogenicity (IT) indices are indicators of fillet lipids quality, and were calculated to determine the potential health impact on human consumers. In our study, the mean values of IA and IT indices were 1.39 and 0.86, respectively; higher values than those recorded by Hoseini et al. (2013). Higher values of IT and IA (>1.0) are detrimental to human health (Ouraji et al 2009).

Trace mineral analysis

The main function of essential minerals include skeletal structure and regulation of acid-base equilibrium. Minerals also constitute component of hormones and enzymes (Alasalvar et al., 2002). Fishes contain very small amounts of mineral. Macro and microelement contents of muscle tissue of fish are self-regulated; however, their concentration is influenced by numerous factors such as seasonal and biological differences, food source and environment (Chandrashekar and Deosthade, 1993; Alasalvar et al., 2002). The variations recorded in the concentration of the different mineral components in the fish examined could have been as a result of the rate in which these components are available in the water body and the ability of the fish to absorb and convert the essential nutrients from the diet or the water bodies where they live. P, K and Ca were predominant elements among 8 minerals analysed and constituted 95.3% and 95.4% of total trace minerals content in cultured and wild C. festae, respectively. The results obtained in this study are consistent with the results of other studies performed into freshwater fish. The present study agrees with the results obtained by Ravichandran et al. (2012) and disprove the decrease order of mineral concentration (K>Na>Mg>Ca). P, Ca, Mg, were higher (Table 5) in cultured than wild fish, however K, Fe and Zn were lower in cultured fish.

P values were similar to those found by Perea et al. (2008) for Nile tilapia with value fluctuating between 191mg/100g - 285mg/100g. Adeniyi, et al. (2012) found K value higher in wild fish than farmed fish in line with the results obtained in this study (farmed fish: 107.8 mg/100g, wild fish: 94.28mg/100g).

Moreover Ca and Mg values were higher than those reported by Mogobe et al. (2015) in different species (Marcusenius altisambesi, Schilbe intermedius, Brycinus lateralis, Oreochromis andersonii, Barbus poechii).

Several studies have considered fish as a major source of Fe for humans (Fraga, 2005), and in the muscle the Fe concentration ranged from 0-18.4 mg/kg in wild and farmer sea bass. In the present study, the Fe values obtained were aligned with FAO (2001) which indicated adequate range of between 0.23mg/100g a 2.1mg/100g.

Mazumder et al. (2008) defined the decreasing order of magnitude (Zn>Fe>Mn>Cu) which is evident in most of the fishes, while in our work, the Cu content exceeded that of Mn.

In contrast to the study developed by Johnston et al. (2006), muscle copper concentrations in cultured Vieja Colorada fish were similar to those found in the wild fish.

Conclusions

The rearing system (cultured or wild) significantly influences most of the analyzed characteristics of carcass and flesh of Vieja Colorada (C. festae). Overall, cultured C. festae is desirable for its greater flesh yield and appears to be the best diet for its higher content of protein, fat, MUFA, PUFA and PUFA/SFA ratio, and lower SFA content and IA and IT indices. From a nutritional point of view and health, the Vieja Colorada (C. festae) flesh presents very desirable characteristics for human consumption. The results of this study revealed that special attention should be paid into the composition and balance of fatty acids in feeding of cultured fish for their impact on human health. These results are of vital importance because they provide appreciated nutritional information of native species in order to produce sources of food with low-fat and high-protein, and also safety food for the consumers in Ecuadorian country.

4.3 MERISTICS AND MORPHOMETRICS CHARACTERS, TRADITIONAL AND TRUSS NETWORK MEASUREMENTS FOR THE CHARACTERIZATION AND DIFFERENTIATION OF TWO POPULATIONS, WILD AND CULTURED, OF VIEJA AZUL (AEQUIDENS RIVULATUS).

MERISTICS AND MORPHOMETRICS CHARACTERS, TRADITIONAL AND TRUSS NETWORK MEASUREMENTS FOR THE CHARACTERIZATION AND DIFFERENTIATION OF TWO POPULATIONS, WILD AND CULTURED, OF VIEJA AZUL (AEQUIDENS RIVULATUS).

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Summary

Twelve meristics, twenty-six traditional morphometrics and thirty-two truss measurements on 104 specimens, wild and cultured, of the *Aequidens rivulatus* were measured to compare overall body shape and structure. Significant differences ($P < 0.05$) between the groups were observed in six (BW, P3, Pre-PvFL, DFL, RDFL and ED) morphometric measurements, two (PcFR and RPcF) meristic characters and seven truss measurements. With truss network system 86.5% and 87.5% of wild and cultured population samples, respectively, were correctly classified by linear discriminant analysis. The results showed that the shape of the tested *Aequidens rivulatus* populations significantly differed from one another depending on the truss measurements that could be explained by the environmental related reasons.

Introduction

In Ecuador, fisheries provide to human communities a source of valuable animal protein (Espinosa-Lemus et al., 2009). Most of the catches are made by artisanal fisheries in areas of rivers, lakes, ponds lagoons, gorges and dams. This activity is usually carried out throughout the year (Muñoz, Alvarez & Capa, 2014). Among the fish most appreciated for the quality of the meat are several species of the Cichlidae Family. Cichlids are distributed in fresh- and brackish waters in Central and South America, Texas, West Indies, Africa, Madagascar, Syria, Israel, Iran, Sri Lanka, and coastal southern India. The cichlids are the most species-rich non-Ostariophysan fish family in freshwaters world-wide, and one of the major vertebrate families, with at least 1300 species and with estimates approaching 1900 species (Kullander, 1998). It is a benthopelagic species. Most Neotropical cichlids occupy lentic habitats within lakes, rivers and streams of slow currents. Body shape quite variable, mostly moderately deep and compressed. There is considerable variation in the shape and of the toothplates and associated dentition, reflecting diet specializations. Most taxa are in the interval 10-20 cm, although lengths range from about 25-30 mm adult size in *Apistogramma* and *Taeniacara*, to about 1 meter in *Cichla temensis*. Cichlids are known by family or genus-level local names, commonly with an adjective to distinguish well-marked species. In Ecuador, higher level names include mojarra and vieja. The *Andinoacara rivulatus* (syn. *Aequidens rivulatus*) is a colorful freshwater fish in the cichlid family. The fish originates from the Pacific side of South America in the coastal waters from the Tumbes River in Peru to the Esmeraldas River in Ecuador. Males and females may reach lengths of 30 cm. In nature, *A. rivulatus* lives in a tropical climate and prefers water with a 6.5–8.0 pH, a water hardness of 25.0 dGH, and a temperature range of 20–24°C.

Over-exploitation of rivers and degradation of natural habitats of these species have caused the decline in the production of fishery resources from the wild (Ajah et al., 2006). Therefore, your domestication is necessary for intensive cultivation in captivity. In the last few years, small and family-owned businesses

have been established where fish are raised and produced for local consumption. This activity must produce food efficiently and be sustainable from the environmental and social point of view (Dias, Simões & Bonecker, 2012).

The phenotypic plasticity of fish is very high, with greater variances in morphological traits both within and between populations than any other vertebrates. The cause of variation in the morphometric and meristic characters can be partly attributed to intraspecific variability, which is under the influence of environmental parameters (Wimberger, 1992). Fish are very sensitive to environmental changes and quickly adapt by changing necessary morphometric character (Hossain et al., 2010). Environmentally induced phenotypic variation, however, may have advantages in the stock identification, especially when the time is insufficient for significant genetic differentiation to accumulate among populations. Morphometric variation between stocks may be applicable for studying short-term environmentally induced variation (Pinheiro et al., 2005). Is important to fish-farmers to know the differences between cultured and wild fish of different species; this could lead them to understand the chemical, physical, nutritional and sensorial profiles of the wild animal and try to reproduce these in their cultured products (Orban et al., 2003).

To characterize strains and/or stocks of the same species which involves the detection of subtle variation in shape, independent of size, the morphometric study of fish is a powerful tool (Elliot et al., 1995), despite the development of biochemical and molecular genetic techniques. For morphological study, morphometric and meristic characters are used. As an alternative to traditional morphometric and meristic techniques, a box-truss network between landmarks has been proposed by Strauss and Bookstein (1982) as a more comprehensive representation of landmarks.

Although comparisons of the morphology between cultured and wild fishes from several species have already been carried out by a number of authors (Swain et al., 1991; Ponton and Mérigoux, 2000; Solem et al., 2006; Solomon et al., 2015), few studies have been carried out on the morphological traits of different populations of the *Aequidens rivulatus* in the rivers of the Ecuador, and the influence of habitat on morphometric and meristic characters. Difference among

cultured and wild *Aequidens rivulatus* stocks based on morphological characters have not yet been studied and, to the best of our knowledge, this is the first such study that has focused on examining the extent of their morphological variations in cultured and wild environments. Since this information is vital for the proper management of the fisheries and for optimum utilization of the resources. Hence present study has been carried out to investigate the morphometric and meristic variations between two populations of *Aequidens rivulatus* (wild and cultured) to illustrate intra-specific variations.

Materials and methods

Ethical note

The study was carried out in accordance with the Ecuadorian national recommendations for fish management, taking into account the rules on animal welfare.

Study area

The study included three areas of the Quevedo River and a fish farm in the province of Los Ríos (Ecuador). The climate of the area is tropical with an average temperature of 25 ºC, an annual rainfall of 2400mm and a relative humidity of 82 %. The salinity of water, both in the river and the fish farm, did not exceed 0.1 %; the pH was between 7.0 and 7.29; the temperature ranged between 19.7 ºC in the river and 24.7 ºC in cultured fish; and dissolved oxygen was between 6.8 and 8.9 mg L^{-1} in the river and fish farm, respectively. The conductivity values were about 145 $mScm^{-1}$.

Data sampling

One hundred four healthy adult fish (following the rules described by Chávez-Lomelí et al., 1988; Konings, 1989) of *Aequidens rivulatus*, comprising 52 individuals from natural habitat (wild population) and 52 from a cultured environment (private fish farms, cultured stock), were collected weekly at dawn over the month of August 2016 with the help of standard fishing gears such as cast and hand nets. Since males and females could not be differentiated morphologically, sexing of the sampled fish was not carried out. Wild fish were

caught from three different locations within their natural geographic distributions in Quevedo River (Los Ríos province, Ecuador). Cultured fish were collected from the fish farm. Directly after catching, the fish were placed at the same time in a mixture of 40 L of ice and 40 L of water (0.8 ºC) until their apparent stunning (20 min) was over. After confirmation of their death, the fish were identified and weighed, and then morphometric measurements and meristic counts were performed.

Body measurements

Measurements, except widths and perimeters, were taken on the left side of fish, by the same person in order to minimize artificial error, and most of the morphometric characters were measured following the conventional method described by Morales et al. (1998) and Diodatti et al. (2008). The fish were measured using a measuring board, measuring tape and digital callipers graduated in millimetres (with an accuracy of 0.01 mm) and then weighed with an electronic weighing balance up to the nearest 0.1 g. Meristic characters were examined according to Froese and Pauly (2007). A total of 38 body measurements were used, including 26 morphometric variables and 12 meristic counts.

Table 1 Definitions of morphometric measurements and meristic counts of Aequidens rivulatus used in this study

Character	Description	Acronyms
Weight	total weight including gut and gonads	BW
Total length	Tip of the upper jaw to the caudal end of the caudal fin	TL
Standard length	Tip of the upper jaw to the tail base	SL
Head length	From the front of the upper lip to the posterior end of the opercular membrane	HL
Eye diameter	The greatest bony diameter of the orbit	ED
Pre-orbital length	Front of the upper lip to cranial eye edge	Pre-OL
Pre-dorsal length	Front of the upper lip to the origin of the dorsal fin	Pre-DL
Pre-pectoral length	Front of the upper lip to the origin of the pectoral fin	Pre-PcL
Pre-pelvic length	Front of the upper lip to the origin of the pelvic fin	Pre-PvL
Pre-anal length	Front of the upper lip to the origin of the anal fin	Pre-AL
Dorsal fin length	From base of first dorsal spine to base of last dorsal ray	DFL
Dorsal fin ray length	From base to tip of the fifth dorsal ray	DFRL
Pectoral fin length	From base to tip of the pectoral fin	PcFL
Pelvic fin length	From base to tip of the pelvic fin	PvFL
Anal fin length	From base of first anal spine to base of last anal ray	AFL
Anal fin ray length	From base to tip of the last anal ray	AFRL
Upper jaw length	Straight line measurement between the snout tip and posterior edge of maxilla	UJL
Body depth 1	Body depth at the level of the first ray of the dorsal fin	AC1
Body depth 2	Body depth at the level of the first ray of the anal fin	AC2
Body depth 3	Body depth at the level of the first radius of the caudal fin	AC3
Body perimeter 1	Body perimeter at the level of the first ray of the dorsal fin	P1
Body perimeter 2	Body perimeter at the level of the first radius of the anal fin	P2
Body perimeter 2	Body perimeter at the level of the last ray of the dorsal fin	P3
Body width 1	Straight line measurement from side to side at the level of the base of first dorsal spine	LC1
Body width 2	Straight line measurement from side to side at the level of the base of first anal spine	LC2
Body width 3	Straight line measurement from side to side at the level of the base of last dorsal ray	LC3
Dorsal fin rays	Number of thorns in the dorsal fin	DFR
Radius dorsal fin	Number of cartilage found in the space between thorns from the dorsal fin	RDF
Pectoral fin rays	Number of thorns in the pectoral fin	PcFR
Radius pectoral fin	Number of cartilage found in the space between thorns in the pectoral fin	RPcF
Pelvic fin rays	Number of thorns in the pelvic fin	PvFR
Radius pelvic fin	Number of cartilage found in the space between thorns in the pelvic fin	RPvF
Anal fin rays	Number of thorns in the anal fin	AFR
Radius anal fin	Number of cartilage found in the space between thorns in the anal fin	RAF
Caudal fin rays	Number of thorns in the caudal fin	CFR
Radius caudal fin	Number of cartilage found in the space between thorns in the caudal fin	RCF
Scales	Number of scales in the lateral line scale	SC
Gills	Number of gills	G

The morphometric technique (Truss Network System) proposed by Strauss and Bookstein (1982) was used. Thirty two truss network measurements were

determined based on 25 anatomical points (landmarks) on the left lateral plane (Figure 1 and 2). The landmarks were: (1) commissure of the mouth; (2) most cranial point of the upper premaxilar; (3) origin of pelvic fin; (4) origin of dorsal fin; (5) origin of anal fin; (6) most cranial point of the base of the tenth spine of the dorsal fin; (7) ending of anal fin; (8) ending of dorsal fin; (9) ventral origin of caudal fin; (10) dorsal origin of caudal fin; (11) most cranial point of caudal peduncle; (12) most caudal point of caudal peduncle; (13) ending of pectoral fin; (14) end of operculum; (15) cranial edge of the eye; (16) caudal edge of the eye; (17) pre-occipital (most posterior aspect of neurocranium); (18) down of operculum; (19) origin of pectoral fin; (20) lower end of the head; (21) anal opening; (22) most cranial point of the lower premaxilar; (23) ending of 1st dorsal fin ray; (24) ending of the last anal fin ray; (25) ending of the pelvic fin radius.

Figure 1. Location of 25 anatomic landmark points designed on the left view of the *Aequidens rivulatus*.

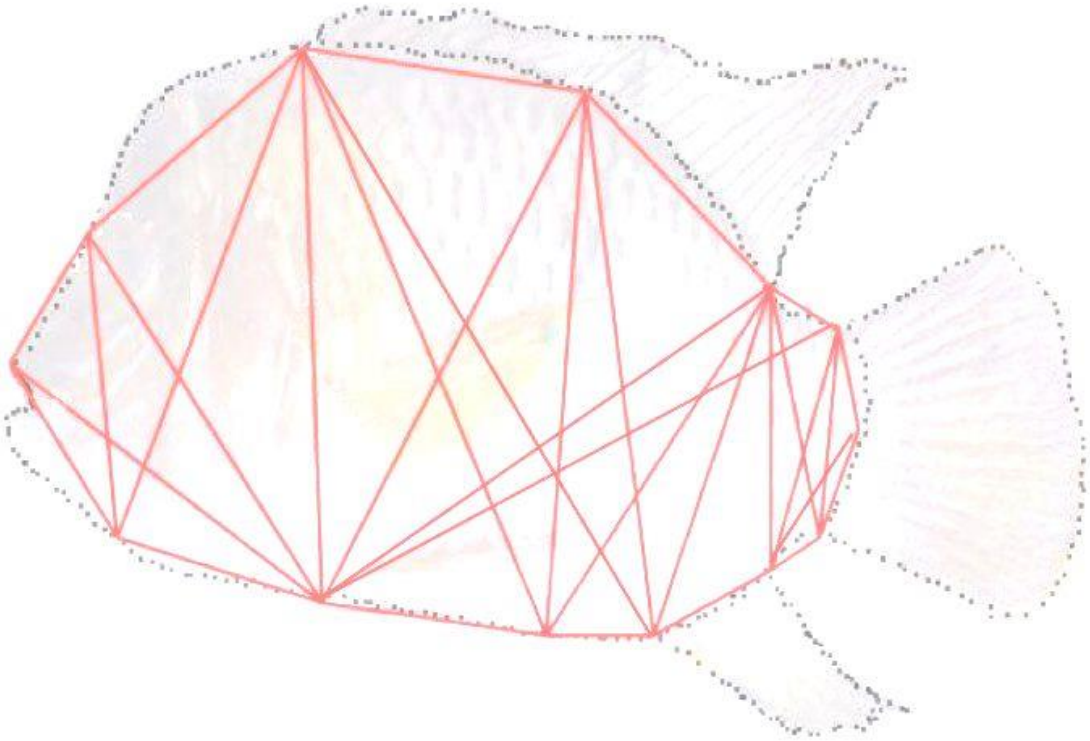

Figure 2. 32 truss characters making a truss network.

Fulton condition factor (K)

The Fulton condition factor (K), a useful index for monitoring of feeding intensity, age and growth rates, was calculated with the following equation: $K = (100 \times BW)/SL^3$, where BW refers to body weight of fish in grams and SL is the standard length of fish in centimetres.

Length-weight relationship

Length–weight relationships were calculated using the allometric regression analysis (Sasi and Berber, 2012). Length–weights were expressed as $BW = a \times SL^b$, and were determined by logarithmic transformation of the linear regression equation: $\log BW = a + (b \times \log SL)$, where BW is the body weight of fish (g), SL is the standard length of fish (cm), *a* is the intercept and *b* the slope of the regression curve (Ruiz-Campos et al., 2010) or growth coefficient. Constants *a* and *b* represent the point at which the regression line intercepts the y axis and the slope of the regression line, respectively.

Statistical analyses

All statistical analyses were performed using SAS University Edition 3.5 (SAS Institute, Cary, NC). Each collection site was considered a priori as a discrete group. To evaluate whether the data have equal variances, a Bartlett test was done prior to further analyses. Means, standard deviation (SD) and coefficient of variation (CV %) were recorded for each population.

The morphometric (continuous) and meristic (discrete) data were analysed separately. Since meristic characters are independent of size and did not change during growth (Turan et al., 2006), the raw data were used in analysis. However, to avoid possible biases produced by size effects on the morphometric variables, all morphometric characters were standardized by the following equation (Elliott et al., 1995): $M_{adj} = M\ (L_s/L_o)^b$, where M is the original morphometric measurement, M_{adj} the size adjusted measurement, L_o the standard length of fish and L_s the overall mean of standard length for all fish from all samples for each variable. The parameter *b* was estimated for each character from the observed data as the slope of the regression of logM on $logL_o$, using all specimens. This method normalizes the individuals in a sample to a single, arbitrary size, common to all samples and, at the same time, maintains the individual variation (Tudela, 1999). It has been successfully used by many researchers in recent years (Salini et al., 2004; Turan et al., 2006). The efficiency of the size-adjustment transformations was assessed by testing the significance of the correlation between a transformed variable and the SL.

Size-adjusted morphometric data and meristic characters were compared by univariate analysis of variance (ANOVA procedure) and Kruskal–Wallis test (NPAR1WAY procedure), respectively, using the group (cultured or wild) as the fixed effect. In addition, the DISCRIM procedure was used to perform a canonical discriminant analysis of size-adjusted geomorphometric data, using the group (cultured or wild) as the grouping variable. The variables that would be included as predictors in the canonical discriminant function were previously selected with the STEPDISC procedure. The probabilities to enter and to stay in the model were both set at $P<0.05$. The option CROSSVALIDATE was included to assess the robustness of the linear discriminant functions obtained.

RESULTS

Morphometric and meristic traits mean values of *Aequidens rivulatus* from cultured and wild specimens are shown in Table 2 and 3. Among the morphometric characters, the most used are the BW (from 99.0 to 228.0 g with a mean value of 154±26.3 g), TL (between 14.7 and 21.8 cm with a mean value of 14.7±1.6 cm), SL (between 11.7 and 17.0 cm with a mean value of 14.3±1.3 cm) and HL (between 3.4 and 6.0 cm with a mean value of 4.9±0.4 cm), with no significant difference (P>0.05) between populations. Head length represented 34.2% of the standard length.

Table 2 Descriptive statistics of the morphometric characters (original data) from Aequidens rivulatus from the Quevedo River (wild) of the Province of Los Rios, Ecuador, and fish-farm (cultured). Percentage respect to SL is reported in brackets.

	All data					Wild		Cultured		*P*
	Mean	Min	Max	S.D.	C.V.	Mean	C.V.	Mean	C.V.	
Weight (g)	154.71	99.00	228.00	26.27	16.98	159.48	17.17	149.94	16.30	0.064
Fulton condition factor	5.40	3.13	8.21	1.30	24.15	5.53	23.85	5.26	24.44	0.294
Total length (cm)	18.37 (128.1)	14.71	21.83	1.56	8.49	18.27	7.78	18.47	9.17	0.511
Standard length (cm)	14.34	11.71	17.00	1.34	9.32	14.36	8.84	14.32	9.87	0.889
Head length (cm)	4.88 (34.2)	3.41	6.00	0.45	9.16	4.87	7.19	4.89	10.83	0.825
Eye diameter (cm)	1.11 (7.8)	0.77	1.42	0.15	13.75	1.07	13.15	1.14	13.78	0.668
Pre-orbital length (cm)	2.12 (14.9)	1.57	3.57	0.33	15.42	2.13	14.79	2.12	16.18	0.937
Pre-dorsal length (cm)	6.31 (44.2)	5.00	7.87	0.56	8.80	6.36	7.85	6.27	9.71	0.398
Pre-pectoral length (cm)	5.65 (39.40)	4.57	7.00	0.45	8.01	5.58	7.50	5.71	8.40	0.165
Pre-pelvic length (cm)	6.26 (43.8)	4.83	8.00	0.62	9.91	6.19	10.25	6.34	9.51	0.218
Pre-anal length (cm)	10.39 (72.5)	5.38	13.40	1.13	10.83	10.31	11.74	10.47	9.92	0.466
Dorsal fin length (cm)	8.78 (61.22)	6.68	10.40	0.84	9.59	8.66	9.56	8.91	9.50	0.127
Dorsal fin ray length (cm)	1.01 (7.1)	0.38	2.00	0.38	37.82	0.88	36.75	1.13	34.82	0.001
Pectoral fin ray length (cm)	4.63 (32.4)	2.14	6.00	0.60	12.95	4.61	10.01	4.66	15.38	0.684
Pelvic fin ray length (cm)	4.63 (32.3)	3.53	6.50	0.61	13.10	4.63	12.29	4.62	13.99	0.976
Anal fin length (cm)	3.07 (21.41)	2.17	4.14	0.32	10.38	3.04	8.85	3.11	11.63	0.263
Anal fin ray length (cm)	3.46 (24.3)	2.00	5.33	0.65	18.78	3.41	19.35	3.52	18.26	0.376
Upper jaw length (cm)	0.64 (4.5)	0.31	0.93	0.13	20.53	0.63	18.58	0.64	22.34	0.553
AC1 (cm)	7.78 (54.2)	5.50	10.66	1.60	20.62	7.91	21.17	7.66	20.10	0.429
AC2 (cm)	7.07 (49.1)	5.10	9.78	1.66	23.55	7.20	24.88	6.93	22.12	0.425
AC3 (cm)	2.62 (18.3)	2.00	3.43	0.47	18.07	2.64	19.55	2.61	16.59	0.767
P1 (cm)	16.28 (114.3)	14.10	20.00	1.05	6.45	16.35	7.16	16.21	5.67	0.492
P2 (cm)	14.99 (105.3)	12.90	18.10	1.12	7.48	15.13	8.34	14.85	6.40	0.203
P3 (cm)	6.02 (42.3)	5.00	7.80	0.48	8.05	6.13	8.39	5.91	7.31	0.023
LC1 (cm)	2.61 (18.3)	2.00	3.00	0.24	9.09	2.61	8.53	2.60	9.70	0.837
LC2 (cm)	1.83 (12.9)	1.40	2.70	0.22	12.25	1.84	11.81	1.83	12.79	0.794
LC3 (cm)	0.91 (6.4)	0.60	1.80	0.17	18.99	0.89	16.78	0.93	20.80	0.284

The position and size of the eye and the different fins (dorsal, pectoral, pelvic, and anal) can help us to characterize morphologically the fish, as well as to detect possible microevolutions derived from the adaptation to new habitats. The eye with an average diameter of 1.1 cm is located approximately 2 cm from the tip of the upper jaw. The origin of the pectoral fin is slightly anterior to the dorsal and pelvic fins, which are located at the same distance from the tip of the upper jaw, with no significant differences ($P>0.05$) between the two populations. The most caudal position is occupied by the anal fin, whose length is approximately 34.96% of the dorsal fin. The pectoral and pelvic fin rays length are similar ($P>0.05$) and longer ($P<0.05$) than that of the anal fin. None of these measurements differed significantly between populations, as when comparing the length of the upper jaw length. Regarding the proportions of the different measures with the standard length, we did not find differences ($P> 0.05$) between populations.

The coefficient of variation of the different measures ranged from 6.45 (P1) to 24.15 (factor K). The measures with lower coefficient of variation were TL, SL, Pre-DL, Pre-PcL, Pre-PvL, DFL, LC1, P2, and P1, which did not exceed 10%, whereas those that presented greater variation were factor K, DFRL, UJL, AC1 and AC2 whose CV was superior to 20%. The coefficients of variation of different morphometric characters were not significantly ($P>0.05$) different between populations, except for PcFL and LC3.

The body measurements related to standard length were compared on the basis of statistic r (correlation coefficient) and b (regression coefficient). The most highly correlated body measurements (data not shown) were TL ($r=0.92$), DFL ($r=0.82$), Pre-AFL ($r=0.80$), Pre-PvFL ($r=0.76$) and Pre-DFL ($r=0.73$), and least correlated were LC3 ($r=0.29$), P2 ($r=0.28$), AFRL ($r=0.26$), LO ($r=0.24$), LC1 and LC2 ($r=0.18$) and DFRL ($r=0.15$). For the other morphometric variables, the correlation coefficient ranged from 0.3 to 0.65. Factor K had a negative correlation coefficient ($r = -0.79$). After standardizing according to Elliot et al. (1995), standard length only showed significant correlations with total length and factor K (Table 3).

Table 3 Significant (P<0.05) Pearson correlation coefficients between standard length and adjusted morphometric characters from *Aequidens rivulatus* from the Quevedo River (wild) of the Province of Los Rios, Ecuador, and fish-farm (cultured).

	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
SL	-0,866	-0,214																						
1	0,452											0,228				0,848	0,762	0,664	0,659	0,672	0,401	0,371	0,229	0,204
2		0,275														0,375	0,336	0,290	0,295	0,311				
3	0,275		0,365		0,227	0,485	0,315	0,380	0,313	0,517		0,217	0,441		0,308									
4				0,366	0,359	0,469		0,508		0,199			0,209		0,373									
5								0,290																
6									-0,220					0,250	0,233									
7							0,408	0,575	0,269						0,458									
8								0,266	0,249														0,218	
9									0,358		0,291	0,211			0,360									
10										0,245	0,349													
12											0,210		0,380											
13												0,205	0,260											
14																			0,224	0,290				
16															0,213									
18																	0,969	0,903	0,627	0,578	0,377	0,253		
19																		0,938	0,587	0,547	0,355	0,210		
20																			0,469	0,427	0,329			
21																				0,800	0,370	0,447	0,352	
22																					0,394	0,459	0,399	
23																						0,273	0,227	0,224
24																							0,483	0,422
25																								0,400

1 = $Weight_{aj}$; 2 = K_{aj}; 3 = TL_{aj}; 4 =H L_{aj}; 5 = Pre-OL_{aj}; 6 = Pre-DFL_{aj}; 7 = Pre-$PvFL_{aj}$; 8 = Pre-AFL_{aj}; 9 = Pre-$PcFL_{aj}$; 10 = DFL_{aj}; 12 = $RPcFL_{aj}$; 13 = $RPvFL_{aj}$; 14 = AFL_{aj}; 15 = $RFAL_{aj}$; 16 = UJL_{aj}; 17 = ED_{aj}; 18 = $AC1_{aj}$; 19 = $AC2_{aj}$; 20 = $AC3_{aj}$; 21 = $P1_{aj}$; 22 = $P2_{aj}$; 23 = $P3_{aj}$; 24 = $LC1_{aj}$; 25 = $LC2_{aj}$; 26 = $LC3_{aj}$.

Among populations, the BW/SL ratio was significantly higher (P<0.05) in the wild population (11.12 vs. 10.47), while the cultivated population showed higher values of Pre-PvFL/SL (44.21 vs. 43.17), DFL/SL (62.34 vs. 60.49), RDFL/SL (7.93 vs. 6.17), and ED/SL (7.99 vs. 7.53) ratios. After standardizing according to Elliot et al. (1995), the mean values of BW, TL, and HL were 154.74±22.29 g, 18.39±0.65 cm and 4.89±0.34 cm, respectively. Among the twenty six transformed morphometric measurements, six characters (BW, P3, Pre-PvFL, DFL, RDFL and ED) were found significantly different (P<0.05) between the groups. BW (159.39 g vs. 150.09 g) and P3 (6.13 cm vs. 5.92 cm) were significantly higher (P<0.05) in wild specimens, while Pre-PvL (6.18 cm vs. 6.35 cm), DFL (8.66 cm vs. 8.93 cm) RDFL (0.88 cm vs. 1.13 cm) and ED (1.07 cm vs. 1.14 cm) were higher (P<0.05) in the cultured population.

For the standard length, the morphometric characters of early maturity (low allometric coefficient) were P1, P2, P3, LC1, LC2 and LC3, whose allometric coefficients were less than 0.2, while those of late maturity were AC1, AC2 and AC3 (b>1.1). TL and Pre-AL showed isometric growth. The remaining morphometric characters had a coefficient b between 0.5 and 0.8.

The meristic characters (Table 4) showed mean values of 24.16±1.12, 23.16±1.12, 12.92±0.98, 11.92±0.98, 5.96±0.34, 4.96±0.34, 11.11±0.69, 10.11±0.69, 15.96±0.81, 14.96±0.81, 19.16± 1.18 and 3.89±0.31 for DFR, RDF, PcFR, RPcF, PvFR, RPvF, AFR, RAF, CFR, RCF, SC and G, respectively. The mean number of DFR, RDF, PvFR, RPvF, AFR, RAF, CFR, RCF, scale on lateral line and gills were not different between fish from these groups (P>0.05) and difference were occurred in PcFR and RPcF (P<0.05), with higher mean values in cultured fish (13.23 vs. 12.61 and 12.23 vs. 11.61, respectively). The coefficients of variation were very low (<7 %), except for PcFR, RPcF and gills (>7%) and similar between populations, except for RPvF and gills.

Dorsal fin rays and radius dorsal fin ranged from 21 to 28 and 20-27, with most in the range of 23–24 (41.3 %) and 24–25 (31.7 %), respectively (Table 4). Pectoral fin rays and radial pectoral fin ranged from 10 to17 presenting most of the 11-12 (25.0%) and 12-13 (47.1%). Pelvic fin rays and radius pelvic fin ranged from 4 to 8, with most in the range of 5-6 (91.3%). Caudal fin rays and

radius caudal fin ranged from 12 to 18, with most in the range 15-16 (37.5%) and 16-17 (18.3%). In anal fin rays and radius anal fin ranged from 8 to 13, presenting most of the 10–11 (56.7 %) and 11–12 (25.9 %) respectively. Significant differences (P<0.05) between cultured and wild were found (data not shown).

The range of the dorsal fin characters was higher for wild (W) than cultured (C) fishes (20-28 vs. 20-26), although 24 (42.3% for W and 40.4% for C) and 25 (30.8% for W and 32.7% for W) were the most frequent classes (Table 3.17). Also, the range for pectoral and caudal fin characters was higher for W fish (11–17 and 13–18) than C fish (11–15 and 14–18), and the most frequent class differed between populations (13=44% for W and 13=30.8% for C, and 16=67.4% for W and 16=51.7% for C). Conversely, the range for pelvic fin characters was higher for C (5-8) than W (5-7) and 6 was the most frequent class (96.2% for W and 86.5% for C). The range was similar for anal fin characters and gills, although with significant differences in the most frequent classes (11= 51.9% for W and 11=61.5% for C, and 4=86.5% and 4=92.3%, respectively).

Table 4 Descriptive statistics of the meristic characters (original data) from Aequidens rivulatus from the rivers (wild) of the Province of Los Rios, Ecuador, and fish-farm (cultured).

	All data					Wild		Cultured	
	Mean	Min	Max	S.D.	C.V.	Mean	C.V.	Mean	C.V.
Dorsal fin rays	24.16	21.00	28.00	1.12	4.65	24.08 [a]	4.26	24.25 [a]	5.02
Radius dorsal fin	23.16	20.00	27.00	1.12	4.85	23.08 [a]	4.44	23.25 [a]	5.24
Pectoral fin rays	12.92	11.00	17.00	0.98	7.60	12.61[a]	6.69	13.23 [b]	7.72
Radius pectoral fin	11.92	10.00	16.00	0.98	8.24	11.61[a]	7.26	12.23 [b]	8.35
Pelvic fin rays	5.96	5.00	8.00	0.34	5.69	5.92 [a]	7.36	6.00 [a]	3.30
Radius pelvic fin	4.96	4.00	7.00	0.34	6.83	4.9 2 [a]	8.85	5.00 [a]	3.96
Anal fin rays	11.11	9.00	13.00	0.69	6.26	11.11 [a]	5.53	11.09 [a]	6.97
Radius anal fin	10.11	8.00	12.00	0.69	6.88	10.11 [a]	6.08	10.09 [a]	7.66
Caudal fin rays	15.96	13.0	18.00	0.81	5.08	16.00 [a]	5.10	15.92 [a]	5.10
Radius caudal fin	14.96	12.0	17.00	0.81	5.42	15.00 [a]	5.44	14.92 [a]	5.45
Scales in the lateral line	19.16	16.00	23.00	1.18	6.17	19.27 [a]	5.91	19.06 [a]	6.44
Gills	3.89	3.00	4.00	0.31	7.93	3.92 [a]	6.86	3.86 [a]	8.92

[a,b] Within a row, means without a common superscript are different (p <0.05).

Table 5 Frequency of meristic characters from Vieja Azul (Aequidens rivulatus) from the Quevedo river (wild) of the Province of Los Rios, Ecuador, and fish-farm (cultured)

	Scales				Dorsal fin rays				Pectoral fin rays				Pelvic fin rays				Anal fin rays				Caudal fin rays			
Score	W		C		W		C		W		C		W		C		W		C		W		C	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
4													1	2	6	12								
5													50	96	45	86								
6													1	2	0	0								
7															1	2								
9																	1	2						
10																	9	17	7	13				
11									1	2	5	10					27	52	32	62				
12									10	19	16	30					14	27	13	25				
13									23	44	26	50					1	2			1	2		
14									14	27	4	8									2	4	2	4
15									3	6	1	2									6	12	10	19
16	1	2							0	0											35	67	27	52
17	5	10	3	6					1	2											7	13	12	23
18	9	17	8	15																	1	2	1	2
19	18	34	21	40																				
20	14	27	14	27																				
21	4	8	5	10	2	4	1	2																
22	1	2	0	0	2	4	3	6																
23			1	2	5	10	8	15																
24					22	42	21	40																
25					16	31	17	33																
26					4	7	2	4																
28					1	2																		

There was no significant correlation (P>0.05) between standardized truss measurements and standard length, indicating that the effect of size was successfully removed with allometric transformation (data not shown). Univariate statistics (ANOVA) showed that nine (point 2 to 17, point 3 to 8, point 3 to 10, point 4 to 5, point 4 to 20, point 6 to 8, point 7 to 11, point 8 to 9, point 10 to 11) of thirty two truss measurements were significantly different (P<0.05) between populations in varying degrees: all truss measurements were higher in the wild population except 4-5 and 6-8 (data not shown).

Seven morphometric variables (2-17, 3-8, 3-21, 4-5, 4-9, 6-9, 8-9) out of 32 were selected as predictors in the canonical discriminant analysis. These variables included measures of the head (2-17), the trunk (3-8, 3-21, 4-5, 4-9, 6-9) and the caudal peduncle (8-9) (Figure 2B). Wilks' lambda (0.42; P<0.001) indicated that the data were appropriate for discriminant analysis, whereas the eigenvalue (1.40) and canonical correlation (0.76) showed that the canonical function had very good discrimination ability. The Mahalanobis squared distance between the cultured and wild populations was 5.47, and the F test of the distance was highly significant (P<0.001). The variables 3-8 and 2-17

showed the highest and lowest standardized canonical coefficients in absolute values (1.54 and 0.33, respectively), thus the former had the greatest discriminating ability among the selected variables. The pooled within-groups correlations with the canonical discriminant function were -0.14, -0.24 and -0.08 for the 3-21, 4-5, and 6-9 measures, respectively, and 0.31, 0.39, 0.07 and 0.32 for the 2-17, 3-8, 4-9 and 8-9 measures, respectively. Since the class means (centroids) for each group's canonical observation scores were -1.17 and 1.17 in the cultured and wild populations, respectively (Figure 2), the 3-21, 4-5, and 6-9 measures were positively associated with the cultured population and the 2-17, 3-8, 4-9 and 8-9 measures were positively related to the wild population. Fisher's linear discriminant functions are shown in Table 6. In the original classification matrices, four cases (7.7%) from the cultured population were misclassified in the wild group and nine cases (17.3%) from the wild population were misclassified in the cultured group. In the cross-validated classification matrices, four cases (7.7%) from the cultured population were misclassified in the wild group and ten cases (19.2%) from the wild population were misclassified in the cultured group. As a result, 87.5% and 86.5% of the original grouped cases were classified correctly in the original and cross-validated classification matrices, respectively. From the analysis through Canonical Discriminant functions depending on the truss measurements it is found that there was no overlapping among the groups that indicates that the two fish group samples are different from the point of landmark counts also.

Table 6 Fisher's discriminant functions for truss measurements

	Cultured	Wild
Constant	-272.21	-272.27
2-17	-2.68	-1.59
3-8	-.09	3.66
3-21	21.08	19.17
4-5	32.11	30.00
4-9	5.50	4.21
6-9	-2.62	-3.76
8-9	44.22	48.13

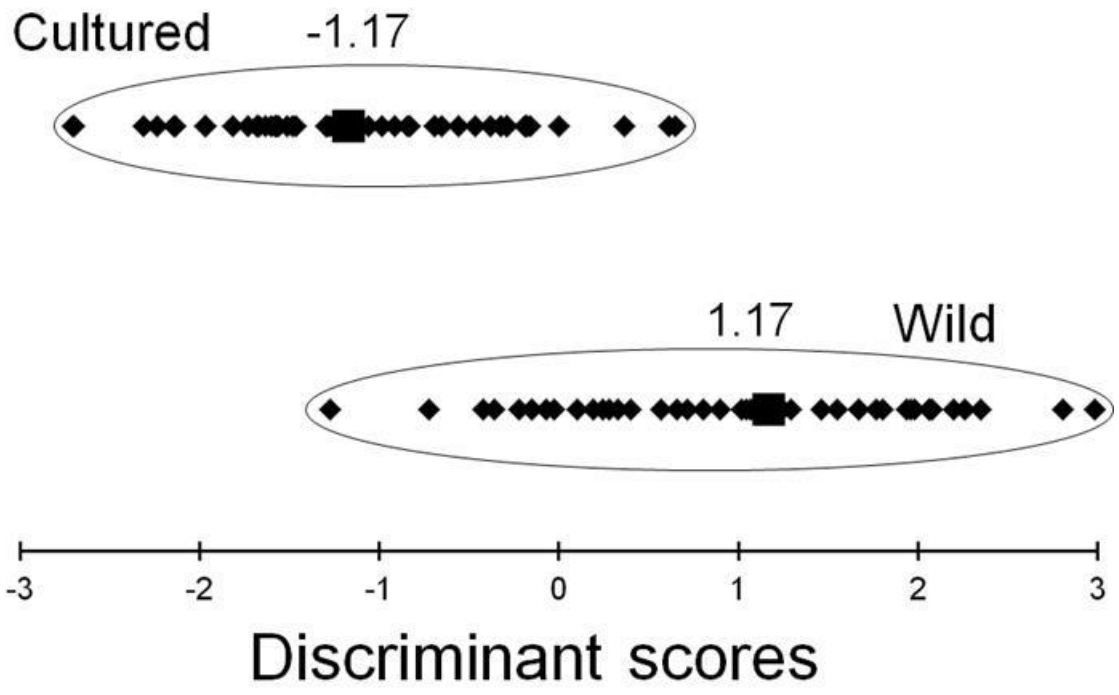

Figure 3 Plot of the individual observation discriminant scores obtained with the canonical discriminant function. For each population class, the values of the class means (centroids) are given

Fulton condition factor

The mean value of the factor K was 5.50±1.30 (Table 2) for the original data set, with mean values of 5.63 and 5.39 for wild and cultured populations, respectively. The coefficient of variation was high (24.2 %). Once the data were adjusted to SL (Elliot et al., 1995), the mean value of the condition factor K was 5.51±1.69. The mean values from K (5.63 and 5.39 for wild and cultured fish) were not significantly (P=0.474) different between populations.

Length–weight relationship

The parameter *b* of the fish studied ranged from a minimum of 0.778 to a maximum of 1.048, with a mean value of 0.922 ± 0.153 (R^2 = 0.263), and with a slightly higher average value in cultured fish when compared with wild fish (0.980±0.186 (R^2 = 0.357) vs. 0.834±0.245 (R^2 = 0.186)).

DISCUSSION

Morphometric and meristic characters

The fish have a great morphological plasticity, which allows them to adapt to different habitats and conditions of the aquatic environment. The cause of variation in the morphometric measurements and meristic counts may range from genetic variability to the influence of environmental parameters (Vladykov, 1934). This happens because some body parts tend to grow at different rates under varying environmental conditions. Therefore, different authors have used morphological and meristic features to identify adaptation processes in wild and cultivated populations of the same species (Solomon et al. 2015; González et al. 2016).

On the basis of the classification of Negi and Nautiyal (2002), of the morphological characters studies from *Aequidens rivulatus*, 11 characters were genetically controlled (range difference <10%), 6 characters were intermediate (range difference 10-15%) and 10 characters were environmentally controlled (range difference >15%). Twenty-four characters have been studied in percentage of standard fish length, from which ten characters were genetically controlled, six characters were intermediate and eight characters were environmentally controlled. All meristic characters were genetically controlled. In general, most morphological and meristic characters can be included in the genetically controlled category of characters, as in previous works (Krishan and Tarana, 2010; González et al., 2016). According to Vladykov (1934), the majority of morphometric characters from fish species with restricted geographic distribution show narrow range. On the basis of the results of our work on *Aequidens rivulatus*, this species fall in the category of fish showing wide distribution, because only 40.7% of their morphometric characters show narrow range differences and are genetically controlled, and the environmentally controlled characters accounted for 33%.

Several authors (Metar et al., 2007; Kanwal and Pathani, 2011) have studied the relative growth of different measures, and conclude that total length, standard length, predorsal and postdorsal lengths are fast growing parts in the fish. The least growing organ in fish was recorded the length of caudal fin in

relation to total length. Results that do not correspond with those obtained in our study.

The animals of the present study were longer (14.34 cm vs. 7.21 cm of standard length) than those studied by Wijkmark et al (2012). Similarly, when comparing the results of our study with those of the aforementioned authors, differences and similarities are found regarding the morphometric characters and their relationships with the standard length. Thus, the proportion of head length and head width are similar (34.2% vs. 34.1%, and 18.3% vs. 19.3%, respectively), whereas eye length is lower in the animals of our study (7.8% vs. 10.5%). The value of this relationship and other relationships between morphometric characters is closely linked to the species, so it is not surprising that differences can be registered between studies. According Vreven et al. (1998) the confinement of domesticated fish affects their growth rate, without allowing elongate the body, which would result in a higher K value. Contrary to this, in our work the value of K is similar in both populations. Results that are also in disagreement with those obtained by González et al. (2016) who registered higher values of k in the wild population.

The morphometric characters allow us to define these fish as: moderately deep, laterally compressed. Head relatively short, snout somewhat produced. Mouth terminal, jaws isognathous. Maxilla extending posteriorly to vertical halfway between nostril and from anterior margin of orbit. Predorsal contour straight ascending, steeper than prepelvic contour, slightly curved posterior to orbit or close to dorsal-fin base. Orbit in middle of length of head, in upper half of depth of head. Description that corresponds to the one reviewed by Wijkmark et al (2012).

Correlation coefficient between different body parts of *Aequidens rivulatus* shows positive and significant strong relationship, except for the factor K which shows negative correlation with most of the morphometric characters studied. When morphometric characters are related to standard length, the most and least correlated variables were similar to those obtained by Krishand and Tarana (2010) and Kanwal and Pathani (2011), although in the current study the values of the correlation coefficients are lower. A possible cause could be in

these authors establish the relationships with the total length. In our study, all the measured morphological variables follow a linear relationship with the standard length, but the low correlation coefficient and the absence of statistical significance (P>0.05) in some of them, it shows that not all increase in the direct proportion which each other.

This study recorded significant differences (P<0.05) between populations only in 2 morphometric parameters (dorsal fin ray length and P3). In contrast, several authors (Barriga-Sosa et al., 2004; Solomon et al., 2015; González et al., 2016) found significant differences between natural and domesticated populations of different species of fish. Also, few meristic characters registered (pectoral fin rays and radius pectoral fin) showed significant differences between populations, in agreement to the results obtained by Solomon et al. (2015) in *Clarias gariepinus*. The causes of morphological differences between populations are often quite difficult to explain (Poulet et al., 2004), but it is well known that morphometric characters can show a high degree of plasticity in response to environmental conditions (Wimberger, 2008). Such morphological differences among different populations of a species may be related to differences in habitat factors such as temperature, turbidity, food availability, water depth and flow (Wimberger, 2008).

Truss measurements are a powerful tool for the analysis of shape, and generally are designed to cover all, or most, of the animal's body (Hossain et al., 2010). The truss network system can effectively be used to distinguish between the hatchery and wild stocks (Turan et al., 2004). An unbiased network of morphometric measurements over the two dimensional outline of a fish removes the need to find the types of characters and optimal number of characters for stock separation, and provides information over the entire fish form (Turan et al., 2004). Bagherian and Rahmani (2007) have considered the variation in size among populations to be largely dependent on environmental parameters, whereas the shape variation may reflect genetic constitution.

Canonical discriminant analysis demonstrated a clear influence of origin in the morphometric variables measured in the present work. The differences between populations in the truss measurements reveal a deeper body in its anterior part,

a longer trunk and a deeper peduncle in the wild specimens, and greater distance between the origins of the dorsal and anal fins in the cultured. These differences might be acclimations to repel the agitated water of the rivers (Wimberger, 2008). The higher number of cases from the wild population misclassified in the cultured group might be ascribed to a higher morphological variability in the former due to the adaptation to the changeability of the natural environment as compared to that in the fish farms, mainly presence of predators and feed availability (Wimberger, 1992; Narvaez et al., 2005).The fact that only seven morphometric variables were needed to separate the two groups indicates that Fisher's linear discriminant could be useful to identify the origin of stocks on a commercial basis (González et al., 2016).

Fulton factor de condición (K)

Condition factor is a useful index for the monitoring of feeding intensity, age and growth rates in fish (Oni et al., 1983) and can be used as an index to assess the status of the aquatic ecosystem in which fish live. The condition factor value of *Aequidens rivulatus* from the current study (5.51) were slightly higher than that recorded by Chukwuemeka et al. (2014) and Anene (2005) in *Tilapia aurea*, *Tilapia galilaea* and *Auchenoglanis occidentalis*, and in four cichlid fish (4.9), respectively. Fagbuaro et al. (2015) recorded significantly lower values (0.68) in *Clarias gariepinus* fish. It is also higher than that registered in a previous work on *Cichlasoma festae* (González et al., 2016) in habitats similar to those of the present study, which shows a greater capacity of food consumption than the species previously mentioned.

The correlation coefficients between the factor K and the total length (r = -0.696) or standard length (r = -0.795) are negative (-0.655 and -0.777 for cultured fish and -0.734 and -0.826 for wild fish, respectively) and statistically significant ($P<0.01$), indicating that a shortened factor occurs with increasing size of the fish. These results are consistent with those obtained in four cichlid species by Anene (2005), who registered a significant and progressive decrease ($P<0.05$) between the size range of 120 and 150 mm, and González et al. (2016) in *Cichlasoma festae* (r = 0.523. Sasi and Berber (2012) recorded

increases in condition factor until the age of 5 years (from 1.6 to 2.5) and a drop below.

The absence of statistical differences (P>0.05) between populations, in disagreement with the results obtained by González et al. (2016), indicates that the quantitative and / or qualitative level of fish feed from fish-farms should be increased in order to improve the growth of these fish.

Length–weight relationship

According to Koutrakis and Tsikliras (2003), parameter *b* for length–weight relationship ranges from 2 to 4. In the current study, the length–weight relationship parameter *b* did not remain within the expected range, and was lower than that reported by González et al. (2016) in Vieja Colorada (*Cichlasoma festae*). Differences in *b* values can result from multiple factors, e.g. the number and length range of the sampled specimens, seasonality, habitat, gonad ripeness, stomach fullness, and growth phase (Sharma et al., 2015). Part of these differences could be due to the fact that in other studies the relationship was established between weight and total length, whereas in our work the relationship was established with the standard length. Also, it could be attributed to that in our study the animals were adults so the growth rates, both absolute and relative, are low. In the case of considering juvenile specimens and adults, the weight-length relationship is isometric and not allometric as in our study. This fact can be verified when comparing with the values obtained in different studies in which length-weight relationship is studied in animals with different age or degree of development (Mir et al., 2015). Likewise, one could also think of nutritional deficiencies that do not allow the normal development of the fish as its length increases. In fish farms, environmental and nutritional conditions should be better than in the natural environment since the coefficient *b* was higher in the cultured than in the wild fishes. Despite this, the optimum levels of growth in these populations were not reached, which has to be taken into account for more efficient production.

CONCLUSIONS

Our results show that the habitat (wild or fish farm) had influence in few of the analysed morphometric measurements and meristic counts from *Aequidens*

rivulatus. Both groups were accurately separated by linear discriminant functions that included seven truss morphometric measures.

In summary, this study has provided valuable morphological information on the shape and structure of *A. rivulatus* that can be used to characterize and visualize the changes that occur as a consequence of adaptation to a different habitat. The authors hope that the information obtained from the present study will be helpful for fisheries, biologists, and taxonomist.

4.4 COMPARISON OF YIELD, FLESH PARAMETERS, PROXIMATE AND FATTY ACID COMPOSITION OF WILD AND CULTURED VIEJA AZUL (*ANDINOACARA RIVULATUS*)

CAPITULO 4. COMPARISON OF YIELD, FLESH PARAMETERS, PROXIMATE AND FATTY ACID COMPOSITION OF WILD AND CULTURED VIEJA AZUL (*ANDINOACARA RIVULATUS*)

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Abstract

In this study, it is aimed to determine the effect of production system (cultured or wild) on the composition of *Andinoacara rivulatus* in Ecuador. One hundred four matured fish samples of *A. rivulatus* were captured in October 2016. These specimens had a mean body weight of 154.71 ± 26.27 g and a total length of 18.37 ± 1.56 cm. The mean slaughter yield and dress-out were similar for cultured and wild specimens. The average fillet yield for cultured fish was significantly higher compared to the wild fish, while the cooking loss was significantly lower. Significant differences were found in wet, ash and protein content in both studied populations. Palmitic, oleic and arachidonic acids had the maximum percentage of saturated and mono and poly unsaturated fatty acids respectively. In cultured and wild fish was also found to differ in the PUFA/SFA, docosahexaenoic acid (DHA)/eicosapentaenoic acid (EPA), and atherogenicity (IA) and thrombogenicity (IT) indices. There were significant

differences in P, K and Mg. The production system (cultured or wild) influences significantly most of the analyzed characteristics of carcass and flesh of *Andinoacara rivulatus***.** These results provide valued nutritional information of native species to produce sources of food with medium-fat and high-protein, and safety food for the consumers in Ecuadorian country.

INTRODUCTION

Fish products freshness and quality has become the key strategic priority for the fish industry and consumers are increasingly aware of fish benefits for human health, and always ask for high quality products. For their nutritional characteristics, fish is considered an excellent source of high quality protein, essential minerals and low-medium fat product (Martínez et al., 2010). Among other properties fish is the best source of polyunsaturated long chain omega-3 fatty acids, which are beneficial to human health. Highlights include eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6) that although can be synthesized in the human body by α-linolenic acid (ALA, 18:3n-3), their efficiency is rather low (Domenichiello et al, 2015) and their inclusion in the human diet is essential (Luczynska. et al., 2014). They both recognize the positive effect of consumption of fish and fish oils on human health. Numerous studies confirm the reduction of the incidence of many diseases, including cardiovascular disease, psychiatric and mental illness. Regarding minerals, fish meat is considered a source of calcium and phosphorus, as well as iron and copper (Izquierdo et al., 2001).

Fisheries have progressively increased in Ecuador and contribute 7% to the total supply of animal protein. In 2011 fishery production were about 663,600 tonnes of which 391,700 tonnes were derived from capture fisheries and 308,900 tonnes from aquaculture. Aquaculture in Ecuador is a source of employment and foreign exchange for the country that contributes to poverty alleviation, food security and maintains the livelihoods (FAO, 2014). The main species of fish that are caught on the coast and Ecuadorian Amazon are *Cichlasoma festae, Andinoacara rivulatus*, *Prochilodus magdalenae*, *Brycon alburnus*, *Leporinus ecuadoriensis*), *Hoplias microlepis)* and *Lebiasina bimaculata* among others (FAO, 2014). The *Andinoacara rivulatus* (syn.

Aequidens rivulatus) (Günther, 1860) or vieja azul, among the freshwater fish is a colorful fish in the cichlid family. This fish is distributed from the Pacific side of South America in the coastal waters from the Tumbes River in Peru to the Esmeraldas River in Ecuador. Males and females may reach lengths of 30 cm. In order to produce and preserve this native species, a conservation programme for native species was developed by the Subsecretaría de Acuacultura of Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (MAGAP).

The increase in world population demanding high amount of fish protein makes it necessary to develop research to increase knowledge of systems and aquaculture products nutritionally (FAO, 2008). According to Tveterås *et al.* (2012) it is estimated that about 3 billion people consume meat of fish and other marine organisms as the main source of protein.

A strategic factor for farmers is to know the differences between cultured and wild fish of different species (González-Artola, 2004; Harlioğlu et al., 2012; González et al; 2016; González et al; 2017; Rodriguez et al., 2017); this could lead them to understand the chemical, physical, nutritional and sensorial profiles of the wild animal and try to reproduce it in their farmed products. Although comparisons of the morphology between cultured and wild fishes from several species have already been carried out by several authors (Solomon et al., 2015; González et al., 2016), differences based on nutritional composition among cultured and wild *Andinoacara rivulatus* stocks, have not been studied yet.

Hence, the aim of this study was to compare the carcass and fillet characteristics, fatty acid composition and nutritional value in muscle tissue of wild and cultured of *Andinoacara rivulatus,* a native species of Ecuador.

MATERIALS AND METHODS

Study Area and Experimental Fish

The study was carried out in three areas of Babahoyo River and a fish farm center located in the Province Los Rios (Ecuador). The area has a tropical climate with an average temperature of 25 °C, an annual rainfall of 2,400 mm

and a relative humidity of 82%. The salinity of water, both in the river and the fish farm, does not exceed 0.1%, the pH was between 7.0 and 7.29, the range of temperature is 19.7ºC and 24.7ºC cultured fish, while the dissolved oxygen in the river and fish farm is between 6.8 and 8.9 mg/l, respectively. The conductivity values are about 145 mS/cm.

One hundred four matured and healthy fish samples of *Andinoacara rivulatus* were captured using fishing nets by local fisherman in October 2016 following the rules described by Frost and Kipling (1980), Chávez-Lomelí et al. (1988) and Konings (1989). These specimens had a mean body weight (arithmetical mean $\pm$ error standard) of 154.71 $\pm$ 26.27 g and a total length of 18.37 $\pm$ 1.56 cm. Since male and female could not be differentiated morphologically, sexing of the sampled fish was not carried out. Wild fishes (n = 52) were caught from three different locations within their natural geographic distributions in Babahoyo River and cultured fishes (n = 52) were collected from three fish farms in the Province Los Rios. Just they were caught, the specimens were kept in a glass flow through aquaria with continuous air and filled with 200 L of dechlorinated tap water, transported alive and housed in two masonry tanks (capacity of 500 L) (dissolved oxygen = 6.20 $\pm$ 0.0 mg/L, temperature = 20.5 $\pm$ 0.2 °C and pH = 5.6 $\pm$ 0.1). The fish rested for 48 h before the experiment, with fasting time of 24 h before stunning. On the day of the experiment, the water in the tank was reduced by half; the fish were quickly caught with a net and transferred to a plastic box (100 L) and kept indoor. For stunning, the fish were placed at the same time in a mixture of 40 L of ice and 40 L of water (0.8 °C) until the apparent stunning was over (20 min). After confirmation of death, the fish were identified, and biometric parameters and pH was performed. Then, the collected fish were rapidly bagged, packed in an undistorted condition and stored at 0 $\pm$ 2 ºC in chilly bins containing ice, and carefully brought to a laboratory in Facultad de Ciencias Pecuarias de la Escuela de Zootecnia de la Universidad Técnica Estatal de Quevedo (Ecuador) until further analysis and processing.

Finally, the study was conducted in accordance with the Ecuadorian national recommendations for fish management, taking into account the rules on animal welfare.

pH Determination

Muscle pH was determined after death (pH_0), at 2 hours (pH_2) and 12 hours (pH_{12}) post-mortem by inserting a pH electrode (portable meat pHmetre, HI99163, Hanna Instruments Ltd, UK) into the Flesh Quality Cut; dorsal part of the fillet posterior to the head. The instrument was frequently calibrated using pH 4.01 and pH 7.00 buffers, and the electrode was also cleaned to obtain consistent results. Muscle pH was measured in duplicate and expressed as mean value from both.

Biometric and Yield Parameters

After death, specimens were kept in boxes with ice in cold stores at 2 °C, and flake ice was added to the boxes as required and analysis started 24 h after death when *rigor mortis* had passed in most of the chilled fishes. Fish were dissected with a scalpel and scissors, and fins, scales, head, entrails, bones and fillet were removed and weighed. Head, guts and skin + fins yield were calculated according to methodology propose by Rutten et al. (2004).

The comparison of cultured and wild vieja azul was based on a series of biometric parameters: total length (TL) and body weight (BW) were measured to the nearest cm and g, respectively. In addition, gutted body weight and fillet weight were utilised used in order to estimate slaughter yield, dress-out, fillet yield and condition factor as expressed in the following equations:

$$\text{Slaughter yield } (\%) = \frac{\text{Gutted body weight}}{\text{Body weight}} \text{x} 100$$

$$\text{Dress out } (\%) = \frac{\text{Body weight} - \text{Gutted body weight}}{\text{Gutted body weight}} \text{x} 100$$

$$\text{Fillet yield } (\%) = \frac{\text{Fillet weight}}{\text{Body weight}} \text{x} 100$$

$$\text{Condition factor} = \frac{\text{Body weight}}{\text{Total length}^3} \text{x} 100$$

Flesh Quality

After 45 minutes filleting, surface colour measurements on right fillets were recorded at three positions using a portable colorimeter (Lutron RGB-1002 Chroma Meter) equipped with light source C and a 2º observed angle, calibrated to a white standard. The L*, a*, b* system colour profile was measured in all harvested fish. The colour variables calculate were *L**, *a** and *b** where *L** describes lightness (+*L** = white, -*L** = black), *a** red-green chromaticity (+*a** = red, –*a** = green) and *b** yellow-blue chromaticity (+*b** = yellow, -*b** = blue) as recommended by CIE (1976). For each fillet, three measurements (along the length of the fillet) were done on the interior part of fillet, and values were combined to one mean value per fish for each of the three colour variables measured. Water holding capacity (WHC) was determined using the method described by Grau & Hamm (1953) and it was measured in two ways: drip loss and cooking loss.

To determine drip loss, two cubes of 10 mm × 10 mm × 20 mm were cut of fresh muscle. The cubes were suspended on a pin inside a sample bottle (200 mL) taking care that the meat did not touch the sides of the bottle and stored for 24 h at 2 $\pm$ 1°C. The amount of drip measured between 24 h and 48 h *postmortem*, as the difference between the sample mass before and after, was expressed as a percentage of the starting mass:

$$\text{Drip loss (\%)} = \frac{\text{Final weight}}{\text{Initial weight}} \text{x} 100$$

To evaluate cooking loss, the samples (approximately 30 g) were trimmed of external fat, weighed prior to cooking, placed in a polyethylene bag and immersed in a water bath (JP Selecta, Barcelona, España) at 80°C until the internal temperature of sample reached 70°C. The temperature was repeatedly monitored by a Type Kflexible high-temperature thermocouple (Hanna, Instruments, EEUU) inserted into the geometric centre of each piece. Once the samples were cooled at room temperature (approximately 15ºC) for 40 min, they were re-weighed (after gently blotting on filter paper). Cooking loss percentage was calculated as follows:

$$\text{Cooking loss (\%)} = \frac{\text{Weight cooked meat}}{\text{Weight raw meat}} \text{x} 100$$

Proximate Composition and Fatty Acid

For analysis of the proximate composition, the fillets of wild (n = 52) and cultured (n = 52) *Andinoacara rivulatus* were used. Samples were homogenized using a 20.000 rpm grinder. After weighing and homogenisation, the fillets samples were dried at 103ºC for 24 h according to AOAC (2000). The crude protein content was measured by the block digestion method (UNE 55-020), ashing was done at 550 °C for 24 h (ISO R-936), and the moisture content was determined by drying at 103 °C for 24 h (ISO R-1442). Fat percentage was measured according to the Soxhlet method (ISO R-1443) using a Foss Tecator AB Soxtec 2050. Analyses were determined in duplicate, according to the mean value of two determinations and expressed in mg per 100 g of raw meat.

Skinned and deboned muscle from individual fish was blended into homogeneous flesh and total lipid was extracted with chloroform/methanol (2:1 v/v) containing 0.01% of Butylated hydroxytoluene (BHT) as antioxidant (Folch et al., 1957). The organic solvent was evaporated under a stream of nitrogen and the lipid content was determined gravimetrically. Aliquots of the lipids extracted were converted to fatty acid methyl esters (FAME) according to the procedure described by Chistie (1993). FAME were separated and identified on GC Perkin Elmer Clarus 500 gas chromatograph with a flame ionization detector (FID) equipped with a TR-FAME capillary column (30 m x 0.25 mm i.d., 0.25 µm film thickness, Shinwa Inc.), using helium as a carrier gas at a flow rate of 0.5 ml/min. The injection and detector were maintained at 250 and 260 °C, respectively. The oven temperature was programmed at 100 °C, followed by an increase of 2 °C/min to 220 °C, with a final hold time of 20 min. Individual fatty acids were identified by comparing their retention times with those of a standard fatty acid mix Sulpeco 37 (Sigma Chemical Co. Ltd., Poole, UK). Nonadecanoic acid methyl ester (19:0 ME) was used as an internal standard. Individual fatty acids (FAS) were expressed as a percentage of total fatty acids identified and mg/g muscle raw tissue of fish, and grouped as follows: saturated fatty acid (SFA), monounsaturated (MUFA), polyunsaturated fatty acid (PUFA), *n*-6 and *n*-3. The PUFA/SFA, DHA/EPA, ∑ *n*-6/∑ *n*-3 ratios, atherogenicity (IA) and thrombogenicity (IT) indices were also calculated.

IA indicates the relationship between the sum of the main saturated fatty acids and that of the main classes of unsaturated, the former being considered pro-atherogenic (favoring the adhesion of lipids to cells of the immunological and circulatory system), and the latter anti atherogenic (inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, thereby preventing the appearance of micro and macro coronary diseases). Finally, IT shows the tendency to form clots in the blood vessels (Simat et al., 2015).

IA and IT indices were calculated by using the Ulbricht and Southgate (1991) equations as follows:

$$\mathbf{IA} = \frac{(\mathbf{C18{:}0}) + (4 \times \mathbf{C14{:}0}) + (\mathbf{C16{:}0})}{(\mathbf{PUFA\ n{-}6\ and\ n{-}3}) + \mathbf{MUFA})}$$

$$\mathrm{IT} = \frac{(\mathbf{C14{:}0}) + (\mathbf{C16{:}0}) + (\mathbf{C18{:}0})}{(0.5 \times \mathbf{MUFA}) + (0.5 \times \mathbf{PUFA\ n-6}) + (3 \times \mathbf{PUFA}\ n-3) + (\mathbf{PUFA}\ n-3/\mathbf{PUFA}\ n-6)}$$

Trace Mineral Analysis

Approximately 1 g of fish raw meat was subjected to the wet mineralisation by Kjeldahl method using a mixture of nitric and sulphuric acid (2:1, w/w) according to Alasalvar et al. (2010). Mineral contents were determined by plasma absorption spectrometer using a 200-DV (Perkin-Elmer, Waltham, EE.UU). The following elements were measured: potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), iron (Fe), zinc (Zn) y copper (Cu). Analyses were determined in duplicate, according to the mean value of two determinations and expressed in mg per 100 g of fish raw meat.

Statistical analysis

A total of 104 fish flesh samples were analysed for different parameters. Normal distribution was checked for all data with Kolmogorov-Smirnoff test and homogeneity of the variances with the Levene test. After verification of normal distribution, the effect of the production system (wild and cultured) on carcass and fillet characteristics, proximate composition, fatty acid composition and trace mineral content was evaluated using one-way ANOVA with the production systems as the fixed effect. Statistical treatment of the data was done by calculating means and standard error of mean. Differences were considered

statistically significant when *P* was lower than 0.05. All statistical analyses were done using SPSS software, version 15.0 for windows (IBM, Chicago, Il, USA).

RESULTS AND DISCUSSION

Fish is the main source of *n*-3 fatty acids which are beneficial to human health, specifically as a source of EPA and DHA *A. rivulatus* is widely consumed by the Ecuadorian population being the one of the main source of these bioactive *n*-3 fatty acid for this population. To the best of our knowledge, this is the first report to investigate the yield parameters, flesh quality, fatty acids profile and trace minerals of wild and cultured of *A. rivulatus* from Ecuadorian country.

Biometric and yield parameters

Biometric measurement of wild and cultured *A. rivulatus* are shown in **Table 1**. The mean body weight and standard length of *A. rivulatus* in the groups compared did not differ statistically. No significant differences were noted in the mean value of the condition factor (K), which were 5.26 $\pm$ 0.18 and 5.53 $\pm$ 1.82 for cultured and wild specimens, respectively. The K value, used as an index to assess the status of the aquatic ecosystem, of *A. rivulatus* from the current study were higher than that recorded by Anene (2005) in four cichlid fish (4.9), and then those registered on *Cichlasoma festae* (González et al., 2016) in habitats similar to those of the present study, which shows a greater capacity of food consumption than the species previously mentioned. Contrary to results obtained by González et al. (2016), did not exist statistical differences ($p > 0.05$) between populations.

These results obtained indicates that the quantitative and/or qualitative level of fish feed from fish-farms should be increased in order to improve the growth of these fish.

Table 1 Biometric measurement and yield parameters of cultured and wild A. rivulatus

	All data (n = 104)	Cultured (n = 52)	Wild (n=52)
Body weight (g)	154.71 ± 2.57	149.94 ± 3.39 **a**	159.48 ± 3.79 **a**
Standard length (cm)	14.33 ± 0.13	14.32 ± 0.19 **a**	14.36 ± 0.18 **a**
Head %	34.81 ± 0.60	31.92 ± 0.79 b	37.69 ± 0.72 a
Guts %	4.90 ± 0.13	5.11 ± 0.21a	4.69 ± 0.16 a
Skin + fins %	30.16 ± 0.57	31.89 ± 0.78 a	28.42 ± 0.76 b
Slaughter yield (%)	95.09 ± 1.13	94.89 ± 2.12 a	95.31 ± 0.16 a
Dress out (%)	5.17 ± 0.14	5.41 ± 2.23 a	4.94 ± 0.17 a
Fillet yield %	30.12 ± 0.44	31.06 ± 0.65 a	29.18 ± 0.58 b

Data are reported as mean value ± SEM. Value in the same row with different letter indices differ significantly statistically at a significance level of $p < 0.05$.

The coefficient of variation of yield parameters (data not show) ranged from 15.51% for fillet yield to 29.74% for guts, with mean values of 17.61% and 19.13% for head and skin + bones, respectively. The percentage of head was significantly ($p < 0.05$) higher in wild fish, while the percentage of skin + fins and fillet were higher in cultured specimens. The results obtained were similar that those found by Gonzalez et al. (2016) for *Cichlasoma festae* in Ecuador.

Flesh quality

The flesh quality characteristics of *A. rivulatus* are shown in **Table 2**. The coefficient of variation (data not show) did not exceed 4.5% at pH values, it was about 16% in L*, 18.36% by cooking loss, 24.57% for drip loss and exceeded 45% in a* and b*. pH *postmortem* is the most important factor which influences the texture of meat; minor changes in pH impact dramatically the connective tissue properties and pH could be considered as a suitable index of quality control of fish meat (Huss, 1995).

Table 2 Flesh quality characteristics and water holding capacity (WHC) of cultured and wild A. rivulatus.

	All data	Cultured (n=52)	Wild (n=52)
pH_0	6.88 ± 0.02	6.74 ± 0.03 **b**	7.01 ± 0.02 a
pH_2	6.57 ± 0.01	6.59 ± 0.02 **a**	6.53 ± 0.02 b
pH_{12}	6.21 ± 0.03	6.27 ± 0.04 **a**	6.16 ± 0.04 **a**
L*	57.09 ± 0.92	57.56 ± 1.26 **a**	56.61 ± 1.35 **a**
a*	2.73 ± 0.20	2.62 ± 0.29 **a**	2.84 ± 0.28 **a**
b*	2.27 ± 0.25	2.06 ± 0.42 **a**	2.48 ± 0.26 **a**
Coking loss (%)	31.19 ± 0.56	28.12 ± 0.59 **b**	34.27 ± 0.75 a
Drip loss (%)	2.75 ± 0.07	2.74 ± 0.11 **a**	2.75 ± 0.08 **a**

Data are reported as mean value ± SEM. Value in the same row with different letter indices differ significantly statistically at a significance level of $p < 0.05$. pH0 = pH at slaughter; pH_2 = pH at 2 hours postmortem; pH_{12} = pH at 12 hours postmortem; L*. a* and b* = instrumental parameters color (CIE L*. a*. b*)

The values for pH_{12}, chromatic variables (L*, a*, b*) and drip loss were not influenced by production system (Table 2). In the first 12 hour *postmortem*, the pH dropped from 6.88 to 6.21, 6.74 to 6.27 and 7.01 to 6.16 in the total population, cultured and wild fish, respectively. The results were in accordance with Robb et al. (2000) and Roth et al. (2009) who reported that muscle pH displayed a rapid decline in muscle pH during the first 12 h *postmortem.* Chromatic variables (L*, a*, b*), ranged from 36.82 to 75.3, from -1.82 to 6.48, from -14 to 8.92, respectively; and drip loss and cooking loss ranged from 1.59 to 4.44 and from 20.03 to 41.14, respectively (data not shown). Santos et al. (2012) and Droval et al. (2012) have used the classification by parameter L* to evaluate the quality muscles prior to killing. L*, a*, b* values indicate a pale meat with high L* value (have a tendency to white), low a* value (have a tendency to red) and low b* value (have a tendency to yellow). None of the variables showed significant differences ($p > 0.05$) among populations. The results of our study were greater that Lima et al. (2015) in Nile tilapia (*Oreochromis niloticus*) who reported value of L* 52.77. As expected, a* and b* values registered in this study (2.76 and 5.54 respectively) were much higher than those recorded in our research. However, our results were similar to those obtained from juvenile Nile tilapia by Girao et al. (2012).

The values obtained for drip loss did not show differences between production system. However, our results were lower than those reported by Intarak et al. (2015) in Panga fish (*Pangasius bocourti* Sauvage) who obtained values of 4.88% to 2.88% with significant decreases with increasing live weight. Differences in cooking loss were found between wild and cultured fish. The percentage of cooking loss was significantly higher in wild *A. ruvulatus*, mainly due to the higher content of wet. This result contrasts with previously reported results by González et al. (2107) that did not find significant differences between cooking loss of wild and cultured *A. ruvulatus*.

Proximate Composition and Fatty Acid

The proximate composition of fish is affected by a several factors such as: size, temperature, salinity, production system and feeding among other (González-Artola, 2004). According to Chandrashetkar and Desthale (1993), the normal variations between the constituents in fish are: 66-81% for wet, 16-21% for protein, 0.2-25% for fat and 1.2-1.5% for ash. The results of proximate analysis of cultured and wild *A. rivulatus* are shown in **Table 3**.

Table 3 Proximate composition (g/100 g wet weight) of culture and wild A. rivulatus

	All data (n=104)	Cultured (n=52)	Wild (n=52)
Wet %	74.35 ± 0.30	72.95 ± 0.49 **b**	75.75 ± 0.19 a
Ash %	1.53 ± 0.01	1.58 ± 0.02 **a**	1.49 ± 0.02 b
Fat %	4.198 ± 0.04	4.24 ± 0.05 **a**	4.15 ± 0.05 **a**
Protein %	22.267 ± 0.19	23.41 ± 0.29 **a**	21.10 ± 0.13 b

Data are reported as mean value ± SEM. Value in the same row with different letter indices differ significantly statistically at a significance level of $p < 0.05$.

The cultured specimens possessed a higher protein and a lower wet content ($p < 0.05$) than wild ones. However, contrary to results reported by other authors (González et al., 2017; Martínez et al., 2010; Busetto et al., 2008; Alasalvar et al., 2002), fat content did not differ significantly ($p > 0.05$) between cultured and wild fish. Mashaii et al. *(*2012) reported similar values to our results for ash

(1.38-1.59%), moisture (75.2-76.9%) and total fat (2.48-4.88%) contents while were lower the protein (17.4-17.9%) content for cultured *Oncorhynchus mykiss* in Turkey. Gonzalez-Artola (2004) classified fish on the basis of their fat content into lean fish (fat less than 2%), low fat fish (fat 2-4%), medium fat fish (fat 4-8%) and high fat fish (fat more 8%). Thus, based on this classification, *A. rivulatus* could be considered a medium fat fish.

With respect to the crude protein, the results obtained in our study were higher than protein levels for common carp (*Cyprinus carpio*) (16% wet weight; FAO, 2008) and for vieja colorada (*Cichlasoma festae*) (17.33 % wet weight; González et al., 2017) but similar to the range of 18.64-22.7% and 18.4-20.8% reported for the *Cichlidae* family by Sulieman and James (2011) and Perea et al. (2008), respectively. Besides, by contrast with other authors (González et al., 2017; Martínez et al., 2010; Alasalvar et al, 2002) were found significant differences between culture and wild fish, probably due to a high dietary protein level in the feed of the cultured fish.

Fish suffers changes in body composition in response to diet and environmental conditions, and the differences found in fatty acid composition between production systems could be attribute to differences between condition in captivity and in the wild. The fatty acid profiles of cultured and wild *A. rivulatus* are listed in **Table 4**. Fifteen fatty acid with carbon chain lengths from 14 to 22 were found in fillets of both fish, including four SFA, two MUFA and nine PUFA. Significant differences ($p < 0.05$) were found in the content of all the fatty acids analyzed between cultured and wild fish except ratio *n*-3/*n*-6 which was similar ($p > 0.05$) between systems.

The percentage of SFA and PUFA was higher in cultured compared with wild fish, whereas its MUFA content was lower. This is probably due to the low content of oleic (18:1 *n*-9) and palmitoleic (16:1 *n*-7) acid in the feed of the cultured fish. As it was previously reported by other authors (Alasalvar et al., 2002), the assimilation patterns of dietary fatty acids in fish muscle reflect the content of the dietary lipid sources. The major fatty acids identified in both fish were palmitic (16:00), oleic (18:1 *n*-9), stearic (18:00) arachidonic (20:4 *n*-6) docosahexaenoic (22:6 *n*-3, DHA) and docosapentaenoic (22:5 n-3) acid.

Table 4 Fatty acid composition of cultured and wild A. rivulatus

Fatty acid (mg/100 mg of total acids)	All data	Cultured (n=52)	Wild (n=52)
Myristic 14:00	1.65 ± 0.02	1.80 ± 0.01 **a**	1.50 ± 0.02 **b**
Palmitic 16:00	23.44 ± 0.02	23.55 ± 0.01 **a**	23.31 ± 0.03 **b**
Margaric 17:00	1.25 ± 0.01	1.32 ± 0.00 **a**	1.19 ± 0.01 **b**
Stearic 18:00	12.94 ± 0.08	13.51 ± 0.04 a	12.32 ± 0.08 b
∑ SFA	39.28 ± 0.13	40.18 ± 0.04 a	38.33 ± 0.09 b
Palmitoleic 16:1 *n*-7	4.19 ± 0.09	3.61 ± 0.07 a	4.81 ± 0.07 b
Oleic 18:1 *n*-9	18.25 ± 0.05	17.93 ± 0.03 a	18.60 ± 0.04 b
∑ MUFA	22.44 ± 0.14	21.53 ± 0.09 a	23.42 ± 0.09 b
Linoleic 18:2 *n*-6	3.16 ± 0.03	3.37 ± 0.01 a	2.93 ± 0.03 b
Stearidonic 18:4 *n*-3	1.17 ± 0.02	1.28 ± 0.01 a	1.04 ± 0.02 b
Arachidonic 20:4 *n*-6 (ARA)	11.34 ± 0.10	10.68 ± 0.04 a	12.04 ± 0.10 b
Eicosapentaenoic 20:5 *n*-3 (EPA)	2.13 ± 0.04	1.84 ± 0.02 a	2.43 ± 0.03 b
Heneicosapentaenoic 21:5 *n*-3	2.15 ± 0.01	2.04 ± 0.01 a	2.26 ± 0.01 b
Adrenic 22:4 *n*-6	4.00 ± 0.09	4.71 ± 0.02 a	3.24 ± 0.04 b
Docosatetraenoate 22:4 *n*-3	2.01 ± 0.03	1.77 ± 0.01 a	2.27 ± 0.02 b
Docosapentaenoic 22:5 *n*-3 (DPA)	7.39 ± 0.19	8.76 ± 0.03 a	5.94 ± 0.05 b
Docosahexaenoic 22:6 *n*-3 (DHA)	9.61 ± 0.08	9.07 ± 0.02 a	10.19 ± 0.07 b
∑ *n*-6	18.49 0.06	18.76 0.04 a	18.21 0.10 b
∑ *n*-3	24.47 0.06	24.78 0.04 a	24.14 0.07 b
∑ PUFA	33.35 ± 0.17	34.47 ± 0.05 a	32.16 ± 0.14 b
∑ PUFA/∑ SFA	0.85 ± 0.002	0.86 ± 0.00 **a**	0.84 ± 0.00 **b**
DHA/EPA	4.59 ± 0.06	4.93 ± 0.04 **a**	4.22 ± 0.07 **b**
∑ *n*-3/∑ *n*-6	1.32 ± 0.003	1.32 ± 0.00 **a**	1.33 ± 0.01 **a**
Atherogenicity index (AI)	0.77 + 0.006	0.81 ± 0.002a	0.72 ± 0.003b
Thrombogenicity index (TI)	0.58 + 0.006	0.62 ± 0.006a	0.53 ± 0.003b

Data are reported as mean value ± SEM. Value in the same row with different letter indices differ significantly statistically at a significance level of $p < 0.05$. SFAs. saturated fatty acids; MUFAs. monounsaturated fatty acids; PUFAs. polyunsaturated fatty acids

Palmitic acid (C16:0) was the primary saturated fatty acid (SFA), contributing approximately 58.6% and 60.8% to the total SFA content of the lipid for cultured and wild fish, respectively. These results were lower than those obtained by Alasalvar et al. (2002) who reported values of 70% to the total SFA content. The total SFA content of lipids were 40.18% and 38.33% for cultured and wild,

respectively. These results are in agreement with values obtained by Łuczynsk et al. (2014) in different freshwater fishes. Thus, the remaining fatty acid found in both fish (about 56%) were mono and polyunsaturated fatty acid (MUFA + PUFA).

Oleic acid was identified as the primary MUFA in both systems and was significantly ($p < 0.05$) higher in wild fish between cultured and wild fish. Alasalvar et al. (2010) also reported oleic acid as the most abundant of the MUFAs. As it was previously found by other authors (Jabeen et al., 2011), this fatty acid has exogenous origin and reflect of diet of the fish. Among saturated and mono-unsaturated fatty acid of our study the highest palmitic acid (16:0) followed by oleic acid (18:1 *n*-9) and stearic acid (18:00) was comparable with the findings of Jabeen et al. (2011) for *Cyprinus carpio*, *Labeo rohita* and *Oreochromis mossambicus* in Indus River (Pakistan) and Łuczynsk et al. (2014) for *Clarias gariepinus*, *Oncorhynchus mykiss*, *Oreochromis niloticus* and *Pangasianodon hypophthalmus* in northeastern Poland.

Regarding to PUFA content, higher ($p < 0.05$) levels were found for cultured that for wild vieja azul. Among this fraction, as it was found by other authors (Martínez et al., 2010; Busetto et al., 2008), *n*-6 fatty acid was significantly ($p < 0.05$) higher in cultured fish. Arachidonic acid (C20:4 *n*-6, ARA) was the dominating fatty acids in both fish and it was significantly higher in wild than cultured fish. According to Pompeia et al. (2012) ARA is a precursor for prostaglandin and thromboxane biosynthesis, so it might facilitate the blood clotting process and attach to endothelial cells during wound healing. The results obtained of ARA content in this study were greater than those obtained by Łuczynsk et al. (2014), Jabeen et al. (2011) and Martínez et al. (2010).

In *n*-3 family fatty acids, docosahexaenoic (22:6 *n*-3, DHA) and docosapentaenoic (22:5 *n*-3, DPA) acid were the most important and these values were greater than results of *C. festae* in similar climatic conditions (González et al., 2017). However, eicosapentaenoic (20:5 *n*-3, EPA) acid value was lower than those obtained by Gonzalez et al. (2017) for *C. festae* in Ecuador. According to Leaf and Webber (1988), DHA and EPA are key

components for a healthy diet in humans. Finally, suitable choice of dietary lipid in cultured fish will allow improve the fatty acids profile, especially in *n*-3 PUFAs.

In our study, no differences between production system were found in *n*-3/*n*-6 ratio (1.32 for all data). These values are higher than those obtained by González et al. (2017) in *C. festae and* Hoseini et al. (2013) in farmed Big head carp (*Hypophthalmichthys nobilis*) and Grass carp (*Ctenopharyngodon idella*). An increase in the human dietary of *n*-3/*n*-6 fatty acid ratio is essential in the diet and nutritionists believe that this ratio should be 0.1-0.2 and consider higher ratios (>0.2) more beneficial to human health (FAO/WHO 1994). Simopoulos (2008) suggested that *n*-3⁄*n*-6 ratio should be kept between 1:1 and 1:4.

The nutritional quality of *A. rivulatus* was evaluated through of atherogenicity (IA) and thrombogenicity (IT) indices which were calculated to determine the potential health impact on human consumers. In our study, the mean values of IA and IT indices were 0.81 and 0.62 for cultured and 0.72 and 0.53 for wild specimens, respectively; similar values to the range reported by Šimat et al. (2015). However, by contrast with Šimat et al. (2015), IA and IT were significantly higher in cultured fish.

Trace mineral analysis

Trace mineral contents obtained are listed in **Table 5.** P, K and Ca were predominant elements among eight minerals analysed. P and K were higher ($p < 0.05$) in cultured fish compared with wild fish. However, the content of Mg was lower in cultured fish. No significant differences ($p > 0.05$) were found in Ca, Cu, Fe, Zn and Mn content. According to Alasalvar et al. (2010) the concentration of trace minerals in fish is influenced by numerous factors such as seasonal and biological differences, food source and environment. P values were lower than those found by Perea *et al.* (2008) for Nile tilapia with value fluctuating between 191 mg/100 g – 285 mg/100 g. In opposite with our results, Gonzalez et al. (2017) found K value lower in cultured than wild *C. festae* in Ecuador. Mazumder *et al.* (2008) defined the decreasing order of magnitude (Zn>Fe>Mn>Cu) which is evident in most of the fishes, while in our work, the Cu content exceeded that of Mn.

Table 5 Mineral contents (mg/100 g) of fish raw meat from cultured and wild A. rivulatus

Trace mineral	All data (n=104)	Cultured (n=52)	Wild (n=52)
P	121.42 ± 0.90	124.38 ± 0.98 [a]	118.46 ± 1.40 [b]
K	100.96 ± 1.43	106.95 ± 1.95 [a]	94.96 ± 1.75 [b]
Ca	184.44 ± 2.56	181.94 ± 4.13 [a]	186.94 ± 3.04 [a]
Mg	11.16 ± 0.17	10.59 ± 0.25 [b]	11.72 ± 0.21 [a]
Cu	0.23 ± 0.01	0.23 ± 0.01 **[a]**	0.24 ± 0.01 **[a]**
Fe	2.54 ± 0.03	2.58 ± 0.04 **[a]**	2.49 ± 0.05 **[a]**
Zn	5.11 ± 0.05	5.03 ± 0.08 **[a]**	5.17 ± 0.07 **[a]**
Mn	0.13 ± 0.00	0.13 ± 0.01 **[a]**	0.14 ± 0.01 **[a]**

Data are reported as mean value + SEM. Value in the same row with different letter indices differ significantly statistically at a significance level of $p < 0.05$.

In summary, rearing system significantly influences most of the analyzed characteristics of carcass and flesh of *A. rivulatus.* The results obtained from this study indicate that nutritional parameters of cultured *A. rivulatus* are more adequate that those of wild *A. rivulatus,* since cultured fish contain high amount of quality protein and *n*-3 and *n*-6 PUFA and adequate *n*-3/*n*-6 ratio. However, from a food safety point view, no differences can be observed between cultured and wild *A. rivulatus*. Finally, no toxicity derived from trace mineral levels were observed.

5. CONCLUSIONES

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Vieja Colorada

CAPITULO I

1. El sistema de cria (silvestre, piscifactoría) influyó significativamente en la mayoría de los caracteres morfométricos y merísticos analizados en la Vieja Colorada (*Cichlasoma festae*).

2. El factor de condición corporal (K) fue significativamente diferente entre sistemas de cría, lo que pone de manifiesto que la alimentación de los peces cultivados puede ser mejorada.

CAPITULO II.

1. El sistema de producción influyó significativamente en la mayoría de los caracteres analizados

2. Los contenidos en proteínas, lípidos y cenizas fueron diferentes entre poblaciones de *Cichlasoma festae* criados en libertad o en piscifactoria

3. Las relaciones PUFA/SFA, DHA/EPA y n-3/n-6 y los indices de atherogenicidad y thrombogenicidad fueron significativamente diferentes entre sistemas de producción.

4. El contenido en Ca, P, K, Mg, Zn y Fe fue significativamente diferente entre sistemas de producción.

Vieja Azul

CAPITULO III

1. El sistema de producción tuvo escasa influencia en las medidas morfométricas y merísticas analizadas en la Vieja Azul (*Aequidens rivulatus*).

2. El análisis discriminate permitió clasificar correctamente el 86.5% y 87.5% de los especímenes de la población silvestre y cultivada, respectivamente.

CAPITULO IV.

1. El sistema de producción influyó significativamente en la mayoría de las características analizadas en poblaciones silvestre y cultivada de Vieja Azul (*Aequidens rivulatus*).

2. La población cultivada de Vieja Azul (*Aequidens rivulatus*) presentó mayor rendimiento al filetado que la silvestre.

3. La carne de la población cultivada de Vieja Azul (*Aequidens rivulatus*) es más adecuada desde el punto de vista nutricional ya que aporta mayor contenido en proteínas y una adecuada relación *n*-3/*n*-6.

4. El sistema de producción influyó significativamente en el contenido en P, K y Mg.

6. RESUMEN

6. RESUMEN

En esta investigación se estudiaron las características morfológicas, merísticas y de calidad de la canal y de la carne de dos especies (Vieja Colorada, *Cichlasoma festae* y Vieja Azul, A. *rivulatus*) de peces de agua dulce de la provincia Los Rios (Ecuador).

En total contamos con 204 ejemplares de ambas especies, la mitad criados en su medio natural y el resto en ambiente controlado (piscifactoria).

Un total de 25 caracteres morfológicos fueron utilizados, de los cuales 21 eran variables morfológicas y 4 variables merísticas (rayos de la aletas dorsal, radios de aleta dorsal, rayos de aleta anal, radios de aleta anal) que se contaron directamente en cada muestra

En la Vieja Colorada determinamos las siguientes variables: peso corporal (incluyendo intestinos y gónadas), longitud total, longitud standard, longitud de la cabeza, longitud pre-orbital, longitud pre-dorsal, longitud pre-ventral, longitud pre-anal, longitud de la aleta pectoral, longitud del hueso faríngeo, profundidad máxima del cuerpo, longitud de la aleta dorsal, longitud de la aleta anal, profundidad del cuerpo a nivel del primer radio de la aleta dorsal, profundidad corporal a nivel del primer radio de la aleta anal, profundidad corporal a nivel del primer radio de la aleta caudal, anchura de la cabeza , anchura del tronco y anchura de la base de la cola, perímetro corporal a nivel del primer radio de la aleta dorsal, a nivel del primer radio de la aleta anal y a nivel de la base de la aleta caudal.

Las variables merísticas fueron el conteo de los radios y cartílagos de las aletas dorsal y anal.

En todos los animales determinamos el índice Fulton (K) mediante la siguiente fórmula:

$K = (100 \times BW) / SL^3$

Y la relación peso longitud standard usando un análisis de regresión alométrica. Esta relación se expresa según la siguiente ecuación:

$BW = a*SL^b$, tras su transformación logarítmica Log BW =a + b*log SL

Donde BW es el peso corporal y SL la longitud standard

Las variables morfológicas fueron utilizadas para discriminar entre poblaciones. El análisis de varianza mostró diferencias significativas entre poblaciones en 21 de las 26 variables analizadas. Encontramos correlaciones significativas entre peso corporal, longitud total, longitud standard, longitud pre-ventral, AC1. LC1 y P1. El índice K y la relación longitud peso arrojaron valores medios de 2.21 y 1.97 (indicando crecimiento alométrico negativo) y 2.86 y 4.07 en cultivados y silvestres, respectivamente. Los índice K fueron significativamente diferentes entre poblaciones, indicando que la alimentación puede ser mejorada. El análisis discriminante permitió separar ambas poblaciones en base a cuatro variables morfométricas.

En la misma población se valoraron variables de calidad de la canal y de la carne. Una vez que los peces llegaron al laboratorio, se procedió a filetearlos calculando el rendimiento al sacrificio:

Rendimiento al sacrificio = 100 x (peso vísceras / peso corporal)

Rendimiento canal:

Rendimiento canal = 100 x (peso –peso vísceras/ peso vísceras)

Y el factor K

Factor K = 100 x (peso corporal / longitud standard^3)

Así mismo, determinamos el pH (a 0, 2 y 12 horas *post-mortem*) y color de la carne (L*, a*, b*). Las pérdidas por goteo y las pérdidas por cocción de valoraron en carne cruda y cocinada

En muestras de carne fresca se determinó en contenido en agua, grasa y proteínas, en ácidos grasos y en minerales (K, Ca, Mg, Mn, P, Fe, Zn y Cu).

El rendimiento al sacrificio y de la canal fueron similares entre poblaciones, mientras que el contenido en grasa fue significativamente mayor en la población cultivada.

El pH, color de la carne y pérdidas por goteo y cocción fueron similares entre poblaciones. Diferencias significativas se encontraron para el contenido en proteínas, lípidos y cenizas. Este estudio mostró que el contenido en ácidos grasos saturados fue mayor que la suma de mono y polinsaturados. Los ácidos grasos palmítico, oleico y linoleico presentaron los mayores porcentajes en saturados, mono y polinsaturados, respectivamente. Entre poblaciones encontramos diferencias significativas en las relaciones PUFA/SFA, DHA/EPA, n3/n6, índice aterogénico e índice trombogénico.

Los sistemas de producción mostraron diferencias significativas en la mayoría de las variables analizadas, lo que es importante desde el punto de vista nutricional.

A semejanza de lo realizado en la Vieja Colorada, en la Vieja Azul (*Aequidens rivulatus*) se determinaron una serie de variables morfológicas y merísticas a fin de poder diferenciar ambas poblaciones y analizar la plasticidad de estos peces cuando pasan de un habita natural a uno cultivado. Se tomaron 12 variables merísticas, 26 morfológicas tradicionales y 32 en red. Se encontraron diferencias significativas en 6 morfológicas (BW, P3, Pre-PvFL, DFL, RDFL y ED), en dos merísticas (PcFR y RPcF) y en seis en red. Con el truss network system se pudo clasificar correctamente al 86.5 5 y 87.5% de los especímenes en las poblaciones salvaje y cultivada, respectivamente.

El estudio de los caracteres de la canal y de la carne de la Vieja Azul (*Andinoacara rivulatus*) arrojo valores medios para el peso vivo de 154.71 $\pm$ 26.27 g y una longitud total de 18.37 $\pm$ 1.56 cm. Los rendimientos al sacrificio y de la canal fueron similares entre poblaciones.

El peso de los filetes fue significativamente mayor en la población cultivada, mientras que las pérdidas por cocción fueron menores. Igualmente se encontraron diferencias entre poblaciones en la humedad, porcentaje de proteínas y cenizas.

Los ácidos grasos palmítico, oleico y araquidónico fueron los que presentaron los mayores porcentajes en cada uno de los tres tipos de ácidos grasos. Los índices PUFA/SFA, DHA/EPA, aterogénico y trombogénico fueron diferentes

entre poblaciones. Así mismo, encontramos diferencias significativas en P, K y Mg.

7. BIBLIOGRAFIA

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