



RESEARCH ARTICLE

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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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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 cooking 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 SFA, MUFA and PUFA respectively. In cultured and wild fish was also found to differ in the PUFA/SFA, docosahexaenoic acid/eicosapentaenoic acid, n-3/n-6 ratios and atherogenicity and thrombogenicity indices. Minerals included Ca, P, K, Mg, Zn, Fe, Cu and Mn. There were significant differences in the first six ones. The production system (cultured or wild) influences significantly most of the analyzed characteristics of carcass and flesh of *C. 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.

Additional key words: freshwater fish; omega-3 fatty acids; proximate analysis; minerals.

Abbreviations used: ALA (α -linolenic acid); BHT (butylated hydroxytoluene); DHA (docosahexaenoic acid); EPA (eicosapentaenoic acid); FAME (fatty acid methyl esters); FID (flame ionization detector); IA (index atherogenicity); IT (index thrombogenicity); MUFA (monounsaturated fatty acid); PUFA (polyunsaturated fatty acid); SFA (saturated fatty acid); WHC (water holding capacity).

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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 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).

In Ecuador, fisheries have progressively increased and contribute 7% to the total supply of animal protein. 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). *Cichlasoma festae*, among the freshwater fish (Boulenger, 1899), is a teleost fish 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 and can be found in rivers, lakes, ponds and dams (Revelo & Elias, 2004; Pacheco & Chicaiza, 2008). It is noted for its white meat, excellent taste and high acceptance in local cuisine (Barnhill *et al.*, 1974). In order to produce and preserve this native species, a conservation programme for native species was developed by the Subsecretaría de Acuicultura of the Ecuadorian Ministerio de Agricultura, Ganadería, Acuicultura y Pesca (MAGAP). According to Revelo & Elias (2004), the cultivation of *C. festae* is becoming more and more popular due to its good growth rate, fecundity, ease of manipulation, ability to grow under suboptimal environmental conditions, disease resistance and good consumer acceptance.

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.

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 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 *C. festae* 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 *Cichlasoma festae*, a native species of Ecuador.

Material 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 19.7°C and 24.7°C 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.

Collection of specimens, sampling and slaughter

One hundred matured fish samples (following the rules described by Konings, 1989) of *C. festae* comprising of 50 individuals from natural origin (wild population) and 50 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) (dissolved oxygen = 6.20 ± 0.0 mg/L, 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 live weight and pH was performed. Then, the collected fish were rapidly bagged, packed in an undistorted condition and stored at $0 \pm 2^\circ\text{C}$ in chilly bins containing ice, and carefully brought to a laboratory in Facultad de Ciencias Pecuarias of Escuela de Zootecnia of the Universidad Técnica Estatal de Quevedo (Ecuador) until further analysis.

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 (pH_0), at 2 h (pH_2) and 12 h (pH_{12}) *postmortem* 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

At the laboratory, the fishes were kept in boxes with ice in cold stores at $2 \pm 1^\circ\text{C}$, 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). Biometric traits as standard length (cm), body weight (g), gutted body weight (g) and weight without head, viscera and skin (g), were utilised used in order to estimate slaughter yield and dress-out as expressed in the following equations:

$$\text{Slaughter yield (\%)} = \frac{\text{Gutted weight}}{\text{Body weight}} \times 100 \quad [1]$$

$$\text{Dress out (\%)} = \frac{\text{Body weight} - \text{Gutted body weight}}{\text{Gutted body weight}} \times 100 \quad [2]$$

Flesh quality

After 45 min 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 2° 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 $10 \text{ mm} \times 10 \text{ mm} \times 20 \text{ mm}$ 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 $2 \pm 1^\circ\text{C}$. 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:

$$\text{Drip loss (\%)} = \frac{\text{Final weight}}{\text{Initial weight}} \times 100 \quad [3]$$

To evaluate cooking loss, the samples ($\sim 30 \text{ g}$) were trimmed of external fat, weighed prior to cooking, placed in a polyethylene bag and immersed in a water bath (JP Selecta, Barcelona, Spain) 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, USA) inserted into the geometric centre of each piece. Once the samples were cooled at room temperature (approximately 15°C) for 40 min, they were re-weighed (after gently blotting on filter paper). Cooking loss percentage was calculated as follows:

$$\text{Cooking loss (\%)} = \frac{\text{Weight cooked meat}}{\text{Weight raw meat}} \times 100 \quad [4]$$

Proximate analyses

Muscle samples were homogenized using a 20000 rpm grinder. Wet, crude protein, total fat and ash percent of fish raw meat were determined 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 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 mean value of two determinations and expressed in mg per 100 g of raw meat.

Fatty acid analysis

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 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 × 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 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, $\sum n-6/\sum n-3$, 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.

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

$$IA = \frac{(C18:0) + (4 \times C14:0) + (C16:0)}{(PUFA\ n-6\ and\ n-3) + MUFA} \quad [5]$$

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

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.* (2011). Mineral contents were determined by plasma absorption spectrometer using a 200-DV (Perkin-Elmer, Waltham, USA). The following elements were measured: potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), iron (Fe), zinc (Zn) and 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 100 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, fatty acid composition and nutritional value 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 at $p < 0.05$. The statistical data were obtained using SPSS software, version 15.0 (IBM, Chicago, IL, USA).

Results

Biometric and yield parameters

Body yield of *C. festae* under two production systems is shown in Table 1. 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, no significant differences were found among guts percentage, slaughter yield and dress-out. The edible portion represents 29.2% of fish weight, higher in cultured compared to wild.

Flesh quality

The flesh quality characteristics of *C. festae* are shown in Table 1. The coefficient of variation did 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 *postmortem* was

Table 1. Biometric, yield parameters, flesh quality characteristics, water holding capacity and proximate composition of cultured and wild *Cichlasoma festae*.

Variables	System	
	Cultured (n=50)	Wild (n=50)
Biometric and yield parameters (%)		
Head	36.06 ± 0.69 ^a	41.44 ± 0.72 ^b
Guts	4.48 ± 0.29 ^a	4.72 ± 0.22 ^a
Skin + bones	31.09 ± 0.59 ^a	28.79 ± 0.67 ^b
Flesh	30.66 ± 0.45 ^a	27.72 ± 0.49 ^b
Slaughter yield	95.52 ± 0.29 ^a	95.28 ± 0.22 ^a
Dress-out	4.74 ± 0.32 ^a	4.98 ± 0.24 ^a
Flesh quality characteristics and water holding capacity		
pH ₀	7.13 ± 0.02	7.17 ± 0.03
pH ₂	6.72 ± 0.02	6.74 ± 0.03
pH ₁₂	6.74 ± 0.03	6.69 ± 0.03
L*	53.77 ± 0.67	55.27 ± 0.91
a*	4.52 ± 0.32	4.50 ± 0.29
b*	5.71 ± 0.42	6.15 ± 0.34
Drip loss (%)	2.75 ± 0.13	2.65 ± 0.12
Cooking loss (%)	30.87 ± 0.96	30.69 ± 0.85
Proximate composition (g/100 g wet weight)		
Wet	78.84 ± 0.34 ^a	79.27 ± 0.26 ^a
Protein	17.86 ± 0.27 ^a	16.80 ± 0.21 ^b
Fat	2.03 ± 0.01 ^a	1.96 ± 0.02 ^b
Ash	1.42 ± 0.01 ^a	1.29 ± 0.01 ^b

Results are expressed as means ± SEM (standard error of mean). pH₀ = pH at slaughter; pH₂ = pH at 2 h *postmortem*; pH₁₂ = pH at 12 h *postmortem*; L*, a* and b* = instrumental parameters color (CIE L*, a*, b*). ^{a,b} Within a row, means with different superscripts are significantly different ($p < 0.05$).

the main factor which influences the quality of meat. In the first one hour *postmortem*, the pH dropped from 7.15 to 6.72, 7.13 to 6.74 and 7.17 to 6.69 in the total population, cultured and wild fish, respectively. This fall took place mainly in the first 2 h *postmortem* (from 7.15 to 6.73, 7.13 to 6.72 and 7.17 to 6.74, 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 (data not shown). L*, a*, b* values indicate a pale meat with high L* value (have a tendency to white), low a* value and low b* value. None of the variables showed significant differences ($p > 0.05$) among populations.

Proximate analysis

The results of proximate analysis of muscle tissue of *C. festae* samples are shown in Table 1. 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.

Fatty acid analysis

The fatty acid profiles of cultured and wild *C. festae* are listed in Table 2. In the present study, more abundant saturated fatty acids were palmitic (27.91%), stearic (9.0%) and myristic (7.12%) fatty acids. Monounsaturated oleic acid was the most abundant (19.74%) fatty acid in fish muscle samples, and linoleic acid was the most abundant (8.19%) polyunsaturated fatty acid. Muscle tissue of *C. festae* included 55.7% saturated, 21.2% monounsaturated and 23.2% polyunsaturated fatty acids.

Besides, significant differences ($p < 0.05$) were found in the content of most of the fatty acids analyzed

Table 2. Fatty acid composition (in mg/g; % in parenthesis) of cultured and wild *Cichlasoma festae*.

Fatty acid and indices ^[1]	System	
	Cultured (n=50)	Wild (n=50)
C6:0	0.46 ± 0.02 ^a (0.042 ± 0.02 ^a)	0.29 ± 0.01 ^b (0.030 ± 0.001 ^b)
C8:0	1.55 ± 0.05 ^a (0.143 ± 0.005 ^a)	1.49 ± 0.03 ^a (0.151 ± 0.003 ^a)
C10:0	2.12 ± 0.10 ^a (0.197 ± 0.010 ^a)	2.94 ± 0.05 ^b (0.297 ± 0.006 ^b)
C12:0	18.82 ± 0.20 ^a (1.747 ± 0.021 ^a)	19.26 ± 0.68 ^a (1.942 ± 0.69 ^b)
C14:0	66.06 ± 0.99 ^a (6.129 ± 0.099 ^a)	92.32 ± 1.18 ^b (9.305 ± 0.24 ^b)
C15:0	16.44 ± 0.19 ^a (1.523 ± 0.016 ^a)	19.07 ± 0.31 ^b (1.921 ± 0.031 ^b)
C16:0	289.89 ± 3.44 ^a (26.838 ± 0.250 ^a)	288.53 ± 5.19 ^a (28.975 ± 0.397 ^b)
C18:0	103.57 ± 1.08 ^a (9.596 ± 0.087 ^a)	83.53 ± 1.03 ^b (8.409 ± 0.091 ^b)
C20:0	17.72 ± 0.26 ^a (1.644 ± 0.026 ^a)	16.97 ± 0.17 ^b (1.711 ± 0.019 ^b)
SFA	573.17 ± 3.72 ^a (53.104 ± 0.215 ^a)	581.12 ± 5.54 ^a (58.460 ± 0.296 ^b)
C16:1 <i>n</i> -7	30.19 ± 0.61 ^a (2.798 ± 0.055 ^a)	38.27 ± 0.54 ^b (3.855 ± 0.053 ^b)
C18:1 <i>n</i> -9	244.15 ± 2.39 ^a (22.617 ± 0.182 ^a)	167.15 ± 1.49 ^b (16.854 ± 0.171 ^b)
MUFA	274.35 ± 4.42 ^a (25.415 ± 0.185 ^a)	205.43 ± 3.89 ^b (20.709 ± 0.180 ^b)
C18:2 <i>n</i> -6	100.38 ± 1.77 ^a (9.307 ± 0.163 ^a)	70.12 ± 1.44 ^b (7.066 ± 0.145 ^b)
C18:3 <i>n</i> -3	31.59 ± 0.45 ^a (2.929 ± 0.042 ^a)	33.01 ± 0.43 ^b (3.326 ± 0.044 ^b)
C20:4 <i>n</i> -6	35.05 ± 0.32 ^a (3.253 ± 0.036 ^a)	33.76 ± 0.59 ^a (3.403 ± 0.061 ^b)
C20:5 <i>n</i> -3 (EPA)	19.58 ± 0.33 ^a (1.815 ± 0.030 ^a)	22.89 ± 0.42 ^b (2.307 ± 0.043 ^b)
C22:6 <i>n</i> -3 (DHA)	45.15 ± 1.56 ^a (4.178 ± 0.139 ^a)	46.91 ± 1.01 ^a (4.728 ± 0.102 ^b)
PUFA	231.75 ± 3.01 ^a (21.481 ± 0.204 ^a)	206.69 ± 2.03 ^b (20.831 ± 0.198 ^b)
PUFA/SFA	0.41 ± 0.01 ^a	0.36 ± 0.01 ^b
DHA/EPA	2.33 ± 0.01 ^a	2.08 ± 0.01 ^b
<i>n</i> -3/ <i>n</i> -6	0.717 ± 0.015 ^a	0.998 ± 0.017 ^b
Atherogenicity index (AI)	1.134 ± 0.012 ^a	1.647 ± 0.022 ^b
Thrombogenicity index (TI)	0.739 ± 0.008 ^a	0.838 ± 0.013 ^b

^[1]SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids. Results are expressed as means ± SEM (standard error of mean). ^{a,b} Within a row means with different superscripts are significantly different ($p < 0.05$).

between cultured and wild fish except for caprylic, lauric, palmitic, SFA, DHA and arachidonic contents which were similar ($p > 0.05$) between systems.

Trace mineral analysis

Table 3 shows the trace mineral composition of the meat of cultured and wild *C. festae*. P, K and Ca were predominant elements among eight 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. No significant differences ($p > 0.05$) were found in Cu and Mn content.

Dicussion

This study investigated the performance, flesh quality, fatty acids profile and traces minerals of wild and cultured of *C. festae*. The results are important since they provide valuable nutritional information in order to produce sources of low-fat, high-protein, and safety food for the consumers in Ecuadorian country.

Biometric and yield parameters

The skeletal muscle (fillet or flesh) is the major part of the edible portion of fish and flesh yield depends on the species, sex and size, structural anatomy of the fish and farming conditions. In the present study, flesh yield was much lower than those presented for tilapia

Table 3. Mineral contents (mg/100 g) of fish raw meat from cultured and wild *Cichlasoma festae*

Mineral	All data (n=100)	System	
		Cultured (n=50)	Wild (n=50)
P	156.23 ± 1.55	166.39 ± 1.52 ^a	146.07 ± 1.84 ^b
K	101.05 ± 0.87	94.28 ± 0.94 ^a	107.81 ± 0.94 ^b
Ca	189.05 ± 2.26	193.15 ± 3.61 ^a	184.95 ± 2.63 ^b
Mg	14.53 ± 0.20	16.26 ± 0.17 ^a	12.80 ± 0.12 ^b
Cu	0.23 ± 0.01	0.23 ± 0.01 ^a	0.24 ± 0.01 ^a
Fe	2.54 ± 0.05	2.08 ± 0.03 ^a	2.99 ± 0.04 ^b
Zn	4.05 ± 0.16	3.24 ± 0.19 ^a	4.86 ± 0.20 ^b
Mn	0.15 ± 0.01	0.15 ± 0.01 ^a	0.16 ± 0.01 ^a

Results are expressed as means ± SEM (standard error of mean). ^{a,b} Within a row, means with different superscripts are significantly different ($p < 0.05$).

(*Oreochromis* sp.) (33%) and channel catfish (*Ictalurus punctatus*) (>38%) and similar to the 32% reported by Neto *et al.* (2012) in Pacu (*Colossoma bidens*) and Tambaqui (*Colossoma macropomum*) fish. Based on production systems, the flesh yield obtained was higher in cultured fish than wild fish (Table 1) and similar than those presented by Sulieman & James (2011) for Nile Tilapia (*Oreochromis niloticus*) who reported values higher in farmed fish than in wild fish (37.1% and 32.2 % respectively). However, the results were lower than those presented by Rørå *et al.* (2001) who indicated values between 40% and 70% in cultured system. The values for flesh yield and dress-out did not agree with Intarak *et al.* (2015) who indicated that dress-out and flesh yield did not change with slaughter weight.

The differences in yield of different part of body could have been caused by the slaughter weight and to food. In addition, factors inherent to cichlids such as the anatomical body shape, head size and final weight influenced in the yield body in these species (Rojas-Runjaic *et al.*, 2011).

Flesh quality

The values for pH *postmortem*, chromatic variables (L*, a*, b*), drip loss and cooking loss were not influenced by production system (Table 1). The pH *postmortem* is the most important factor which influences the texture of meat; minor changes in pH impact dramatically the connective tissue properties (Huss, 1995). The pH could be considered as an appropriate index of quality control of fish meat. In this study, the drop of pH within 12 h after death was 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*,

then between 12 and 24 h decline was less pronounced and from 24 h pH did not show variations, indicating that the fish were reaching its end pH.

The values obtained for drip losses and cooking losses were higher than those found by Wangtueai & Vichasilp (2015) in Nile tilapia, who reported cooking and drip losses values fluctuating between 17.78% - 26.37% and 0.7 - 3.95%, respectively. Intarak *et al.* (2015), in Panga fish (*Pangasius bocourti* Sauvage), reported values of 4.88% to 2.88% for drip loss, with significant decreases with increasing live weight.

L*, a* and b* value indicate a pale meat and the results of our study were greater than Lima *et al.* (2015) in Nile tilapia who reported value of L* 47.53 and 52.77 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 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 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 (Chandrashekar & Deosthale, 1993).

The results obtained in this study were similar than those obtained for Nile tilapia (Michelato *et al.*, 2016). In a study in Turkey of cultured *Oncorhynchus mykiss* (Mashai *et al.*, 2012), the protein (17.4 - 17.9%) and ash (1.38 - 1.59%) contents were similar than our results, while the moisture (75.2 - 76.9%) and total fat (2.48 - 4.88%) contents were lower and higher, respectively. In general, the wet contents in the muscle fish of this study were

within the range reported by Jabeen & Chaudhry (2011) and Campagnoli de Oliveira *et al.* (2010). Fat content was affected by production systems and this variation in the total fat content was consistent with the conclusions of Gonzalez-Artola (2004) and Jabeen & Chaudhry (2011). Fish is often classified on the basis of their fat content into lean fish (fat<2%), low fat fish (fat = 2 - 4%), medium fat fish (fat = 4 - 8%) and high fat fish (fat>8%) (Gonzalez-Artola, 2004). Based on this classification, *C. festae* is considered a lean fish (Table 1).

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

Fatty acid

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.

More than 50% of the SFAs identified, palmitic acid (C16:0) was the most abundant, ranging from 26.8% to 28.9%. Other studies also reported this fatty acid as the most abundant (Aggelousis & Lazos, 1991). Caproic (C6:0), capric (C10:0), myristic (C14:0), pentadecanoic (C15:0), stearic (C18:0) and arachidic (C20:0) acids were significantly different between systems but no significant differences were found for total SFAs. Oleic acid was the principal MUFA in both systems. Difference was observed between cultured and wild fish. Alasalvar *et al.* (2011) also reported oleic acid as the most abundant of the MUFAs.

Regarding to PUFA content, linoleic acid (C18:2n - 6) was the dominating fatty acids according to results found by Jabeen & Chaudhry (2011) for *Cyprinus carpio*, *Labeo rohita* and *Oreochromis mossambicus* in Indus River (Pakistan). Linoleic acid values were different ($p<0.05$) among systems, being higher in cultured system.

In n-3 family fatty acids, EPA, DHA and linolenic acid were the most important as Romero *et al.* (2000) and Mashaii *et al.* (2012) indicated. According to Leaf & Weber (1988), DHA and EPA are key components for a healthy diet in humans. Although in this study DHA and EPA values were low, it is important to highlight that, contrary to expectations, wild fish had higher EPA content (22.89 mg/g). Finally, suitable choice of dietary lipid in cultured fish will allow improve the fatty acids profile,

especially in n-3 PUFAs. In n-6 family fatty acid, linoleic acid was the most important and arachidonic acid (C20:4 n-6) content was higher in cultured fish ($p<0.05$) and this fatty acid is precursor for prostaglandin and thromboxane biosynthesis aiding the blood clotting process during wound healing (Jabeen & Chaudhry, 2011).

In our study, the SFA content was higher than unsaturated fatty acids. Higher amounts of SFA in the present study might be assumed as a disadvantage of these fish. The n-3/n-6 ratio in this study (0.86) was similar than those 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 and in wild fish 0.99; differences were observed between two production systems ($p<0.05$). Those results could be due to wild fish probably ingests higher rate of natural foods containing more EPA and DHA.

IA and IT indices are indicators of flesh 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 than those values recorded by Hoseini *et al.* (2013).

Trace mineral analysis

According to Alasalvar *et al.* (2011) the concentration of trace minerals in fish is influenced by numerous factors such as seasonal and biological differences, food source and environment. In this study, P, K and Ca were predominant elements among eight minerals analysed and constituted 95.3% and 95.4% of total trace minerals content in cultured and wild *C. festae*, respectively. The results obtained were similar than those obtained by Ravichandran *et al.* (2012); P, Ca, Mg, were higher in cultured than wild fish, however K, Fe and Zn were lower in cultured fish. P values were similar than those found by Perea *et al.* (2008) for Nile tilapia with value fluctuating between 191mg/100 g and 285mg/100 g. Adeniyi *et al.* (2012) found K values higher in wild fish than farmed fish, in line with the results obtained in this study (farmed fish: 107.8mg/100 g, wild fish: 94.28 mg/100 g). Moreover, Ca and Mg values were higher than those reported by Mogobe *et al.* (2015) in different freshwater species (*Marcusenius altisambesi*, *Schilbe intermedius*, *Brycinus lateralis*, *Oreochromis andersonii*, *Barbus poecheii*). In the present study, the Fe values obtained were in consonance with FAO (2001), who indicated adequate

range from 0.23 mg/100 g to 2.1 mg/100 g. 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.

Hence, rearing system significantly influences most of the analyzed characteristics of carcass and flesh of *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. Finally, from a nutritional point of view, *C. festae* flesh presents very desirable characteristics for human consumption.

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