Proximate composition and flesh quality of red bellied pacu, *Piaractus brachypomus*, cultured in two different closed systems

Marinela Barrero[1*], Ana Paredes[1], Oneida Romero[2] y Germán A. Poleo[2]

[1]Universidad Central de Venezuela, Facultad de Ciencias, Instituto de Ciencia y Tecnología de los Alimentos, Apartado Postal 47097. Caracas. Venezuela. Correo electrónico: marinela.barrero@ciens.ucv.ve.
[2]Universidad Centroccidental "Lisandro Alvarado", Estación de Piscicultura, Apartado 400. Barquisimeto, estado Lara, Venezuela.

ABSTRACT

The objective of this study was to evaluate chemical and sensory characteristics of red bellied pacu (*Piaractus brachypomus*) cultured in two types of intensive systems, Heterotrophic System (HS) with zero water exchange and Recirculating Aquaculture System (RAS), and compare them to those cultured in a semi intensive flow-through system (control). Red bellied pacu were cultured for 192 days in 6 concrete tanks at the rate of 150 fish per tank in 4.8 m^3 of water (31.25 fish/m^3). Protein content were significantly different ($P<0.05$) between treatments. Moisture differed significantly between fish from RAS and control. No changes were observed for lipid contents; however, lipids profile showed that EPA and DHA disappeared on HS, and were constant on RAS. Sensory evaluation did not present significant differences among treatments regarding odor, flavor, texture and color.

Key words: Zero exchange system, heterotrophic system, Biofloc, *Piaractus brachypomus*.

Composición proximal y calidad de carne del morocoto *Piaractus brachypomus,* cultivado en dos diferentes sistemas cerrados

RESUMEN

El objetivo del presente estudio fue evaluar química y sensorialmente las características de morocotos, *Piaractus brachypomus,* cultivados en dos sistemas de cultivo: intensivo sistema heterotrófico (HS) con cero intercambio de agua y un sistema de recirculación de agua (RAS); y compararlos con los cultivados en un medio intensivo de flujo de agua continuo (control). Los morocotos se cultivaron durante 192 días en 6 tanques de concreto a razón de 150 peces por tanque y en 4,8 m^3 de agua (31,25 peces/m^3). El contenido de proteína resultó ser significativamente diferente ($P<0.05$) entre los tratamientos. La humedad resultó ser diferente entre peces de RAS y control. No se observaron cambios en los lípidos; sólo, el perfil de lípidos mostró que el EPA y DHA desaparecen en HS, manteniéndose constante en RAS. La evaluación sensorial no presentó diferencias significativas entre los dos tipos de tratamientos respectos al olor, sabor, textura y color evidenciando que el cultivo intensivo de morocotos en sistemas de biofloc no tiene efectos negativos en la calidad de los peces.

*Palabras clave***:** Sistemas cero recambio, sistemas heterotroficos, Biofloc, *Piaractus brachypomus*.

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INTRODUCTION

The high installation and operation cost of closed systems makes them unattractive for investors in developing countries. In order to tackle this problem, researchers have been working on closed systems with zero water exchange rates which reduce the use of expensive biofiltration equipment and power. In some of these systems the production of high quantities of phytoplankton in the water column is encouraged in order to reduce nitrogen levels and produce oxygen (green systems). In other systems the combination of phytoplankton, heterotrophic and autotrophic bacteria suspended in the water column, photosynthetic suspended-growth systems or Biofloc, (Hargreaves, 2006; Avnimelech, 2009) is promoted with a high C/N ratio and strong aeration to reduce the levels of ammonia. Although, panaeid shrimp (MacNeil, 2000; Boyd and Clay, 2002), tilapia (Milstein *et al*., 2001; Rakocy*et al*., 2004), channel catfish, (Green, 2010) and hybrid striped bass (Milstein *et al*., 2001) have been cultured in this kind of system, not all aquatic animals can be grown in high levels of suspended solids and relative high rates of ammonia, nitrogen and nitrites.

A fish that fits these characteristics is the South American fish, *Piaractus brachypomus*, known by its common name as red bellied pacu, morocoto in Venezuela and Colombia, and pirapitinga in Brasil, Bolivia and Peru. This fish, from the Charasidae family, is found in rivers with high sediments (brown waters) in the Amazon and Orinoco river basin and represent an important source of income and protein (Izquierdo, 2000) for the riverside population.

At the moment, *P. brachypomus* has become one of the most cultured fish in the Amazon and Orinoco river basin region due to its easy adaptation to culture conditions, its omnivore characteristics, rapid growth and good flesh quality (Hernández 1994; Mesa and Botero 2007). This fish is usually cultured in a semi-intensive way in earthen ponds and to a lesser degree in floating cages (Gomes *et al*., 2006). Previous findings indicate that *P. brachypomus* can be cultured at high densities in biofloc systems (Poleo *et al*., 2011). However, the chemical and sensory characteristics of fish grown in such conditions have not been studied.

The objective of this work was to perform a proximal analysisand to analyze and compare flesh quality of *P. brachypomus*, grown in two different closed systems in high densities against those grown in a semi-intensive manner in a flow through system.

MATERIALS AND METHODS

Nine hundred fingerlings of *P. brachypomus*, were randomly and evenly distributed in six 4.8 m^3 concrete tanks (31.25 fish/m^3) at the Aquaculture Research Station of the Universidad Centro Occidental "Lisandro Alvarado", situated in Yaritagua, Yaracuy State, Venezuela, located at 500 meters above sea level. Three tanks were set to having zero water exchange (heterotrophic system, HS) and the three were connected to a bioclarifier (green water recirculating aquaculture system, RAS).

All six tanks had strong aeration, using a 2 hp regeneration blower, which supplied oxygen and produced a flow of 26.6 cm/s that maintained the solids suspended. Tanks which served as control had a continuous supply of water (flow- through system) with a density at 2 fish/m^3. Fish were fed once a day to apparent satiation for 192 days, with a commercial diet containing 28% crude protein (Puripargo 28, Purina Venezuela). At the termination of the production trial, five fish from each tank (15 per treatment) with an average weight of 555±102,3 g for HS, 524,13±59,7 g for RAS and 528±167 g for control, were sacrificed and stored at 5^{o}C, until used for sensory and proximate analysis.

Chemical analyses

Proximate composition of samples from each treatment was determined in triplicate, according to AOAC procedures (AOAC, 2005).

Sensory evaluation

Fish samples were placed in polyethylene bags, randomly coded and cooked in a microwave oven for 5 min. Samples were served on trays to six experienced panelists familiar with *P. brachypomus*. Panelists scored the products for texture, color, odor, and taste based on a 9 point hedonic scale (1 extremely disliked and 9 extremelyliked, with more than 5 being an acceptable product).

Fatty acid profile

The fatty acid profile of fish samples was determined according to Folch *et al*. (1957) methods. Total fatty acids were extracted from samples and transesterified. The methyl ester derivatives were analyzed by gas chromatography with a Hewlett-Packard 5880-A (Avondale, PA, USA). The mobile phase was nitrogen, oven temperature was 200ºC on isothermic conditions; detector and injector temperature was 250ºC. Fatty acids' quantification was obtained utilizing heptanoic acid as standard ($C_7H_{14}O_2$) 1.5 µl/ml, before esterification (Sigma-Aldrich, St. Louis, MO, USA).

Statistical Analysis

Test data was examined via analysis of variance ANOVA using a SAS 9.1 program. Fisher´s least significance differences (LSD) was used to compare data means at P< 0.05.

RESULTS AND DISCUSSION

This study was carried out in order to find out the composition and organoleptic characteristics of *P. brachypomus* reared in water with zero exchange rate and high content of suspended solids (HS) or in a biofloc (RAS) and those grown in a flow-through system (control). Although, culture of this South American fish in high densities in closed system, up to 13 kg/m^3, has been tried (Poleo *et al*., 2011), the flesh composition and sensory characteristics needed to be assessed in order to examine consumer quality standards. No significant differences (P<0.05) in moisture were observed between fish grown in the closed system (HS), however, this was not the case when fish samples from the controls were compared with samples from RAS (Table 1). There were no differences (P<0.05) in protein, lipids or ash between treatments and control fish, whereas fish in RAS had higher (P<0.05) moisture than the control fish (Table 1). HS fish was higher (P<0.05) in protein than RAS fish, but were similar (P<0.05) in other components.

Previous researchers have reported differences in the organoleptic traits between cultured and wild fish (Nettleton, 1992; Cahu, 2004; González 2006; Grigorakis, 2007), however little has been done to compare the quality of fish grown in different culture systems. Odor of fish samples showed no difference among individual tanks regardless of the system where the fish were reared (Table 2). Texture and color presented no significant differences between control and HS treatment or among individual tanks evaluated. It has been shown that organoleptic characteristics, quality of flesh, odor, texture and color of fish depend on the conditions where they were captured or cultivated (Pullela, 1979; Alasalvara *et al*., 2002; Grigorakis, 2007). Control-reared fish were scored higher (P<0.05) on texture than RAS fish and on color than fish from both treatments.

However, all scores ranged between liked slightly and liked moderately. Valente *et al*., (2011), studying sensory characteristics from distinct production systems (intensive, semi-intensive, integrated and extensive) in Southern Europe, reported that the sea bream external color, taste and odor as well as fatty acid content vary depending on the system where fish were cultivated. They also reported that the flesh from intensive systems seems firmer and denser, having smaller white fibers and higher density in the dorsal muscle. However, in this study, only slight differences were observed in organoleptic characteristics - among treatments.

No significant differences in fatty acid composition were observed between samples of fish from the control tanks and the two closed systems (Table 3). However, PUFA 20:3 n-6 and 22:2 n-6 were not found in samples from HS and the ratio n-3/n-6 was higher for samples from HS than those from control and RAS fish. Rahnan *et al*., (2000) reported that fresh

Table 1. Proximate composition (% ± SE) of red bellied pacu, *Piaractus brachypomus*, cultured in a heterotrophic (HS), recirculating (RAS) and a flow-through (control) aquaculture system.

Treatment	Moisture	Protein	Lipids	Ash
Control	76.02 ^{a} ± 0.47	18.32 ^{ab} ± 0.43	3.15 ^{a} ± 0.005	1.75 ^{b} ± 0.50
HS	76.47 ^{ab} ± 0.28	19.32 ^{b} ± 0.31	2.59 ^{a} ± 0.10	1.12 ^{a} ± 0.01
RAS	76.74 ^{b} ± 0.08	17.78 ^{a} ± 1.02	2.68 ^{a} ± 0.17	1.17 ^{ab} ± 0.01

Data presented are the means from 3 measurements. Numbers within the same column with same letter had not significant difference (P<0.05).

Table 2. Sensory evaluation scores of red bellied pacu, (*Piaractus brachypomus)* muscle cultured in a heterotrophic (HS), a recirculating (RAS) and a flow-through (control) aquaculture system.

Treatment	Texture	Odor	Flavor	Color
Control	6.87 [b]	6.13 [a]	6.39 [a]	7.00 [c]
HS	6.64 [ab]	6.07 [a]	6.25 [a]	6.01 [b]
RAS	6.59 [a]	5.91 [a]	6.09 [a]	5.96 [ab]

Data presented are the means from 7 measurements (judges). Numbers within the same column with the same letter had not significant difference (P<0.05). Panelists scored based on a 9 point hedonic scale (1 extremely disliked to 9 extremely liked).

water fish were made up of monounsaturated fatty acids (17–53%), followed by saturated (15–43%) and polyunsaturated (12–25%) fatty acids. The total *n-6* fatty acids (2.43–26.2%) were found to be higher than the *n-3* (1–11%), regardless of treatment.

Most of these fish had a*n-3/ n–6* ratio of less than 1 except for *Siamese sepat* (3.38), *Black siakap* (2.20) and *Tilapia* (1.26). Valente *et al*., (2011) studied the quality differences of gilthead sea bream from distinct production systems in Southern Europe (Intensive, integrated, semi-intensive or extensive systems) and found that lipid content offish from extensive systems was significantly lower than values observed forfish reared intensively. However, in this study it was found that samples from the less intensive systems showed the best *n 20:3/n-6*ratio.

It is well known that the fatty acid composition of fish depends on different factors such as species, age, freshwater or marine origin, diet, farmed or wild (González *et al*., 2006) and probably on the type of culture systems in which they are raised. Palmeriet al. (2008) stated that the concentration of saturated (SFA), monounsaturated (MUFA) and highly unsaturated (HUFA) fatty acids were not significantly affected by purging time, while polyunsaturated fatty acids (PUFA), $n-3$ and $n-3$ HUFA were significantly higher in purged fish compared to unpurged fish.

Although the culture of fish in zero exchange systems is increasing and extensive research has been carried out in different areas, the effect of biofloc on the proximate composition and flesh quality has not yet been studied. Only slight differences were found on the fatty acid composition among fish grown in the two intensive systems and in the flow-through system, indicating that the quality of the fish was not affected by any of the culture conditions used in this work.

CONCLUSIONS

This work demonstrated for the first time that red bellied pacu can be cultured in a Biofloc System without losing its flesh quality.

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Table 3. Fatty acid composition (%) from muscle of red bellied pacu, (Piaractus brachypomus) cultured in two different closed systems, heterotrophic (HS) and recirculating aquaculture system (RAS) and a flow through system (control).

Fatty Acids	Control	HS	RAS
Saturated (SFA)			
11:0	0.078	0.138	0.178
14:0	2.725	3.364	3.109
15:0	0.173	0.200	0.202
16:0	21.535	22.557	21. 787
17:0	0.214	0.217	0.273
18:0	9.212	9.415	8.941
21:0	0.216	0.179	0.220
22:0	0.399	0.429	0.447
23:0	1.615	0.931	0.944
24:0	0.123	0.144	0.174
Monounsaturated (MUFA)			
14:1	0.1~2	0.209	0.197
16:1 n-7	5.179	5.043	5.131
17:1	0.097	0.083	0.088
18:1 n 9 (trans)	0.219	0.227	0.205
18:1 n-9 (cis)	26.083	25.537	26.685
22:1	0.581	0.694	0.677
24:1	0.129	0.413	0.140
Polyunsaturated (PUFA)			
18:2 n-6 (trans)	0.296	0.356	0.320
18: 2 n-6 (cis)	11.974	12.794	12.765
18:3 n-6	0.081	0.123	0.105
18:3 n-3	0.945	0.957	0.973
20:1 n-6	0.653	0.594	0.762
20:2 n-6	0.299	0.328	0.298
20:3 n-6	0.043	0	0.036
20:3 n-3	0.041	0	0.049
20:4 n-6	0	0	0.446
22: 2 n-6	3.067	0	0.541
20:5 n-3	3.109	3.177	2.832
22:6 n-3	4.400	5.766	4.445
Unknowns	6.305	6.06	6.968
n-3/n-6	0.52	0.70	0.32

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