ARTÍCULO ORIGINAL/ORIGINAL ARTICLE

Inclusion of fermented aquatic plants as feed resource for Cachama blanca, *Piaractus brachypomus*, fed low-fish meal diets

La inclusión de plantas acuáticas fermentadas en dietas con bajo contenido de harina de pescado para Cachama blanca, *Piaractus brachypomus*

A inclusão de plantas aquáticas fermentadas em dietas baixas em farinha de peixe para a Pirapitinga, *Piaractus brachypomus*

Yorcelis Cruz-Velásquez[1], *Claudia Kijora*[2], *Vianys Agudelo-Martínez*[3], *Carsten Schulz*[4]

[1] Ingeniera Pesquera, PhD, Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt Universität zu Berlin, Germany and Instituto de Investigaciones Tropicales de la Universidad Del Magdalena. Santa Marta, Colombia
[2] PhD (Dr. habil), Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt Universität zu Berlin, Germany
[3] Ingeniera Pesquera, MSc., Instituto de Investigaciones Tropicales de la Universidad del Magdalena, Santa Marta, Colombia
[4] Prof. Dr., GMA – Gesellschaft für Marine Aquakultur mbH, Büsum, Germany and Institute for Animal Husbandry at the Christian-Albrechts-University of Kiel, Germany
Email: yorcelis.cruz@hu-berlin.de

Recibido: octubre 30 de 2014 **Aceptado**: noviembre 28 de 2014

Abstract

The production of the Amazonian fish Cachama blanca has been rising continuously and its cultivation has become heavily dependent on the provision of supplementary feed at low cost. Information on the suitability of locally available, cheap feed sources for this fish is required. The locally available duckweeds (*Lemna minor* and *Spirodela polyrhiza*) and water fern (*Azolla filiculoides*) were tested in Cachama blanca evaluating growth performance, feed conversion ratio, and digestibility. A total of five diets, four test diets (35% crude protein) supplemented with fermented duckweeds (DW) and water fern (WF) at 15% and 25% inclusion level and a control diet without aquatic plants, were compared. Ingredients were processed in a micro extruder. Diets were based on a low-fish meal diet. A total of 390 fish (1.6 ± 0.02 g) were randomly selected and stocked into fifteen 250 L plastic tanks providing three replicates per diet. Tanks were arranged in a recirculating system comprising a biofilter and aeration with a turn-over of and a daily water exchange. Fish were fed to apparent satiation twice a day for 60 days. Fish from each tank were weighed collectively every 2 weeks to monitor growth and after 8 weeks final biomass of each tank was recorded. Data from each treatment were subjected to one-way analysis of variance (ANOVA) of the triplicate groups (n=3). Fish fed on DW15 and WF15 revealed significantly higher ($P<0.05$) SGR and weight gain than fish fed the other diets. Feed intake did not vary among diets ($P>0.05$). FCR and PER were also better ($P<0.05$) for fish fed on DW15 and WF15 than for fish fed on DW25 and WF25 but not significant compared to the control diet. Apparent digestibility coefficients decreased significantly ($P<0.05$) in DW25 and WF25 diets. Fish feed supplementation with the fermented aquatic macrophytes at 15% inclusion level improved the growth performance of Cachama blanca (*P. brachypomus*) fed on low-fishmeal-diets.

Key Words: digestibility, duckweeds, fermentation, growth performance, water fern.

Resumen

La producción del pez amazónico Cachama blanca ha ido en continuo aumento y su cultivo se ha vuelto dependiente en gran medida de la disposición de alimento suplementario a bajo costo. Por eso se requiere información sobre la idoneidad de las fuentes de alimentación disponibles a nivel local que sean más económicas para este pez. Las lentejas de agua (*Lemna minor* y *Spirodela polyrhiza*) y el helecho de agua (*Azolla filiculoides*), disponibles localmente, fueron probadas en dietas para Cachama blanca evaluando el desempeño del crecimiento, conversión alimenticia y digestibilidad. Un total de cinco dietas: cuatro dietas de experimentación con un contenido de proteína cruda de 35%, suplementadas al 15% y 25% de inclusión con lentejas de agua (DW) y Azolla (WF) fermentadas, y una dieta control sin plantas acuáticas, fueron comparadas. Todos los ingredientes fueron procesados en una extrusora de micro-tornillo. Todas las dietas fueron basadas en un bajo contenido de harina de pescado. Un total de 390 peces (1,6 ± 0,02 g) fueron seleccionados al azar y distribuidos en quince tanques de plástico de 250 L con tres réplicas por dieta. Los tanques fueron dispuestos en un sistema de recirculación con un biofiltro y aireación constante y un recambio diario de agua. Los peces fueron alimentados hasta aparente saciedad dos veces al día durante 60 días. Los peces de cada tanque fueron pesados colectivamente cada 2 semanas para monitorear el crecimiento y después de 8 semanas se registró la biomasa final en cada tanque. Los datos de cada tratamiento fueron sometieron a un análisis de varianza (ANOVA) de los grupos por triplicado (n = 3). Los peces alimentados con las dietas DW15 y WF15 revelaron un crecimiento (SGR) y ganancia de peso significativamente mayor (p <0,05) al de los peces alimentados con las otras dietas. El consumo de alimento no varió entre las dietas (P> 0,05). El FCR y PER fueron mejores (P <0,05) para los peces alimentados con DW15 y WF15 que para los peces alimentados con DW25 y WF25 pero no hubo diferencias significativa en comparación con la dieta control. Los coeficientes de digestibilidad aparente disminuyeron significativamente (P <0.05) en las dietas DW25 y WF25. El suplemento del alimento con las plantas acuáticas fermentadas al nivel de inclusión de 15% mejoró el desempeño del crecimiento de la Cachama blanca (*P. brachypomus*) alimentada con dietas de bajo contenido de harina de pescado.

Palabras clave: digestibilidad, lenteja de agua, fermentación, crecimiento, Azolla

Resumo

A produção do peixe amazônico Pirapitinga tem crescido continuamente e seu cultivo tornou-se dependente em grande medida da provisão de ração suplementar a baixo custo. Por este motivo se faz relevante a informação acerca de fontes de alimentação locais que sejam mais econômicas para a cultura deste peixe. As lentilhas de água (*Lemna minor* e *Spirodela polyrhiza*) e o feto de água (*Azolla filiculoides*), disponíveis localmente, foram testadas para a Pirapitinga avaliando o desempenho do crescimento, conversão alimentícia e digestibilidade. Um total de cinco dietas: quatro dietas de experimentação com um conteúdo de proteína crua de 35%, suplementadas a 15% e 25% de inclusão com lentilhas de água (DW) feto de água (WF) fermentados, e uma dieta de controle sem plantas aquáticas foram comparadas. Todos os igredientes foram processados numa micro extrusora. Todas as dietas foram baseadas em um conteúdo baixo de farinha de pescado. Um total de 390 peixes (1.6 ± 0.02 g) foram selecionados aleatoriamente e estocados em quinze tanques de plástico de 250 L com três réplicas por dieta. Os tanques foram foram dispostos em um sistema de re-circulação com um bio-filtro e aeração constante, e renovação diária de água. Os peixes foram alimentados até a saciedade aparente duas vezes ao dia durante 60 dias. Os peixes de cada tanque foram pesados coletivamente cada 2 semanas para monitorar o crescimento e depois de 8 semanas foi registrada a biomassa final de cada tanque. Os dados de cada tratamento foram submetidos a uma análise de variância (ANOVA) dos grupos triplicados (n = 3). Os peixes alimentados com as dietas DW15 e WF15 revelaram um crescimento (SGR) e ganho de peso significativamente maiores (P<0.05) ao dos peixes alimentados com as outras dietas. O consumo de alimento não variou entre as dietas (P>0.05). O FCR e PER foram melhores (P<0.05) para os peixes alimentados com DW15 e WF15 que para aqueles alimentados com DW25 and WF25 mas não houve diferença significativa em comparação com a dieta controle. Os coeficientes de digestibilidade aparente diminuíram significativamente (P <0.05) nas dietas DW25 e WF25. O suplemento do alimento com as plantas aquáticas fermentadas ao nível de inclusão de 15% melhorou o crescimento de crescimento da Pirapitinga (*P. brachypomus*) alimentada com dietas de baixo conteúdo de farinha de pescado.

Palavras-chave: digestibilidade, lentilhas de água, fermentação, crescimento, Azolla

Introduction

The tropical fish Cachama blanca (*Piaractus brachypomus*) plays an important role in the regional economy of the Amazon and Orinoco river basins from Colombia. Characterised by a delicate taste and a broad market acceptance it acquires good prices on the local market. As its natural populations do not support market demands, its aquaculture production increased substantially over the last years (Lochmann *et al.*, 2009). Therefore an optimisation of culture techniques becomes priority in particular an efficient feeding, which represents a major expenditure in aquaculture operations in general.

In Colombia, which occupies the fifth place among the major aquaculture producing countries in Latin America with an aquaculture production of 60.072 tonnes/year (Florez-Nava, 2007), the production of Cachama has been rising continuously. At the same time, its cultivation has become heavily dependent on the provision of supplementary feed at low cost. As the majority of research has focused on plant ingredients commonly used in fish feed such as soybean and wheat derivates, information on the suitability of locally available, cheap feed sources for this fish is required.

Aquatic macrophytes are often considered as weeds in many aquatic environments as they grow very fast and cover the surface of ponds. In order to control their high productivity they are frequently harvested and used as livestock feed (Brabben 1993; Rodriguez and Preston 1996; Franklin *et al*., 2008). The suitability of aquatic macrophytes as feed sources in fish diets is highly dependent on the characteristics of the available plant species, their growth conditions and the species-specific requirements of fish. Aquatic macrophytes have not been yet assessed as dietary ingredients in diets for *Piaractus brachypomus*.

As many plant based ingredients, aquatic macrophytes are low digestible and are thus frequently further processed to increase their nutritional value. Processing of this plant material by lactic-acid fermentation has shown to reduce significantly the content of antinutritional substances and fibre present in the raw aquatic macrophytes (Cruz *et al*., 2011). As a result digestibility of the fermented aquatic plants is higher than that of the sundried aquatic plants for the Cachama blanca (Cruz *et al*., 2011). The aquatic macrophytes used in this study were fermented before inclusion in the diets.

The objective of this study was to investigate the effects of the inclusion of fermented aquatic macrophytes in low-fish meal diets (3% fishmeal) on the growth performance, feed utilisation and digestibility of Cachama blanca (*Piaractus brachypomus*) juveniles.

Material and methods

Experimental diets

Five diets containing approximately 350 g kg^{-1} crude protein (CP) and 17 kJ/g gross energy (GE) were prepared. The control diet was formulated mainly with plant products (soy cake, corn gluten, rice bran and wheat bran), see Table 1.1. The maximum supplementation level (25%) of the fermented aquatic macrophytes in the experimental diets was calculated according to the apparent digestibility coefficients (ADC's) of the main protein ingredients, as determined by Vásquez-Torres (2007), and the ADC's of the fermented duckweeds (*Lemna minor*, *Spirodela polyrhiza*) and water fern (*Azolla filiculoides),* as determined by Cruz *et al*., (2011), for Cachama blanca.

Table 1.2 shows the composition and nutritional content of the experimental diets. All diets contained 3% fish meal to enhance palatability and 0.5% of chromic oxide as inert marker. Aquatic macrophytes were included as fermented duckweeds at 15% (DW15) and 25% (DW25), and as fermented water fern Azolla at 15% (DW15) and 25% (DW25). Fermentation was carried out as described by Cruz et al. (2011) through the supplementation with Lactic acid bacteria (LAB) inoculants and molasses. The dietary ingredients, after mixing homogeneously, were processed in a micro extruder (Microextruder Exteect, Brazil) at temperatures of 65°C and pelleted to 4 mm diameter. The diets were dried at ambient temperatures within 4 hours and subsequently frozen at -4°C until utilized. The diets were

Table 1.1. Protein, lipid and energy content of the ingredients used for feed formulation based on a dry matter basis (g kg^{-1}).

Ingredients	Protein	Lipids	Carbohydrates	Energy (kJ g^{-1})
Fish meal[1]	717.3	90.0	20.00	21,3
Soy cake[1]	456.6	17.0	350.0	19,3
Corn gluten[1]	576.6	21.0	250.0	23,2
Rice bran[1]	123.7	15.0	550.0	8,96
Wheat bran[1]	146.9	36.0	615.0	19,5
Fermented duckweeds[2]	241.0	31.0	439.6	13,1
Fermented fern water[2]	2264.0	31.0	442.6	11,5

[1] Obtained from ITALCOL Alimentos Concentrados © (Villavicencio, Colombia)
[2] Duckweed (Lemna minor and Spirodela polyrhiza) and water fern (Azolla filiculoides) were harvested as wild or uncultivated material from water bodies in Colombia and afterwards fermented.

prepared in the *Instituto de Acuacultura de los Llanos (IALL)* at the Universidad de los Llanos, Villavicencio (Colombia). The nutrient content of the diets was analysed according to AOAC (2005).

Culture system and experimental design

A total of 390 Cachama blanca fingerlings were obtained from a regional producer in Villavicencio (Colombia) and transported to the Instituto de Investigaciones Tropicales at the Universidad del Magdalena (Colombia). Fish were fed a commercial diet for 4 weeks prior to stocking in order to adapt them to the experimental conditions. Following fish were randomly selected and stocked into fifteen 250 L plastic tanks providing three replicates per diet. Individual initial weight of fish was 1.6±0.02 g (mean±SD). Tanks were arranged in a recirculating system comprising a biofilter and aeration with a turn-over of and a daily water exchange. Water parameters were monitored weekly (26.9±0.93 °C water temperature and 160.2±10.4 mg/L $CaCO_3$ hardness).

Table 1.2. Formulation and proximate composition of experimental diets with macrophytes (DW – duckweed, WF – water fern) as alternative, cheap feedstuff at 15% and 25% and the control used in an 8 week feeding trial in Cachama blanca.

Ingredients	Control Diet	DW15	DW25	WF15	WF25
Fish meal	30.0	30.0	30.0	30.0	30.0
Soy cake	250.0	250.0	250.0	250.0	250.0
Corn gluten	200.0	200.0	200.0	200.0	200.0
Casein	5.0	0.0	0.0	0.0	0.0
Rice bran	50.0	50.0	50.0	50.0	50.0
Wheat bran	365.0	160.0	0.0	150.0	0.0
Fermented duckweeds	0.0	150.0	250.0	0.0	0.0
Fermented water fern	0.0	0.0	0.0	150.0	250.0
Alfa-cellulose	0.0	60.0	120.0	70.0	120.0
Carboxymethyl cellulose	25.0	25.0	25.0	25.0	25.0
Fish oil	20.0	20.0	20.0	20.0	20.0
Sunflower oil	20.0	20.0	20.0	20.0	20.0
Vitamin premix[1]	10.3	10.3	10.3	10.3	10.3
Mineral premix[2]	10.3	10.3	10.3	10.3	10.3
Ascorbic acid (Stay C-35)[3]	5.0	5.0	5.0	5.0	5.0
Cr_2O_3	5.0	5.0	5.0	5.0	5.0
Proximate Composition					
Dry Matter	920.8	933.6	938.6	916.3	933.5
Ash	67.2	72.5	76.1	81.9	95.6
Crude Protein	357.8	354.1	344.0	353.5	344.5
Ether Extract	56.1	53.3	60.7	51.3	74.7
Crude Fiber	68.2	100.1	133.7	95.6	137.2
NFE[4]	450.7	420.0	385.5	417.7	348.0
GrossEnergy (kJg-1)	18.4	17.7	17.6	17.2	17.1

[1] Rovimix vitamin: ®Lab. Roche S.A. 0.5 (Vit A 8.0*106 UI, Vit D3, 1.8*106 UI, Vit E 66.66g, Vit B1 6.66g, Vit B2 13.33g, Vit B6 6.66g, Calcium pantothenic 33.33g, Biotin 533.3mg, Folicacid 2.66g, Ascorbicacid 400.0g, Nicotinicacid 100.0g, Vit B12 20.0mg, Vit K3 6.66g, cspvehicle 1.0Kg.

[2] Micro-minerals premix: ®Lab. Roche S.A. 1.0 (Composition per 100g the product: Mg 1.0, Zn 16.0, Fe 4.0, Cu 1.0, I 0.5, Se 0.05, Co 0.01).

[3] Vitamin C, StayC-35

[4] Nitrogen-free Extract (NFE) = 100-(Ash+ Protein+ Fibre+ Fat)

Sampling

Fish were fed to apparent satiation twice at day (0900 and 1700 h) for 60 days. Fish from each tank were weighed collectively every 2 weeks to monitor growth and after 8 weeks final biomass of each tank was recorded. At the end of the experimental period, three fish from each replicate were sampled as bulk sample (n=3 per treatment) for carcass analysis and stored at –20°C. For each treatment (n=3), survival, growth parameters, specific growth rate (SGR), weight gain (WG), feed conversion ratio (FCR) and protein efficiency ratio (PER) were determined according to the formulas in Table 1.3.

Apparent nutrient digestibility

After the 8 weeks experimental period, a 3 weeks study on the apparent digestibility was conducted providing the diets used in the feeding trial, but feeding only once daily at 0900 h. Faeces were collected by siphoning from the bottom of the tanks at intervals of 1 h over a period of 8 h post-feeding or after feeding. The ADC's of dry matter, ash and protein of the test diets were calculated using chromic oxide (Cr_2O_3) as inert marker following the formula described by Nose (1960):

$$ADC_{diet} = 100 - \lfloor 100 \times (\%Cr_2O_{3diet} / \%Cr_3O_{3faeces}) \times (\%Nut_{faeces} / \%Nut_{diet}) \rfloor$$

Where:

ADC_{diet} = Apparent digestibility coefficient of the nutrients or energy in diets
$\%Cr_2O_{3diet}$ = % of chromium content in diets
$\%Cr_2O_{3faeces}$ = % of chromium content in faeces
$\%Nut_{diet}$ = % of nutrient or energy in diets
$\%Nut_{faeces}$ = % of nutrient or energy in faeces

Chemical analyses

Analysis of dry matter, ash, lipids, crude fibre and crude protein for diets, faeces and muscle were made according to the AOAC (2005) procedures. Gross energy (GE) was determined by using an adiabatic bomb calorimeter (PARR 121 EA, USA). Spectro photometrically determination of chromic oxide in diets and faeces was performed following the method of Furukawa and Tsukahara (1966).

Statistical analyses

Data from each treatment were subjected to one-way analysis of variance (ANOVA) and are presented as mean ± standard deviation (SD) of triplicate groups (n=3). Analysis was carried out with SPSS 17.0 (Version 19) software package and data were analysed for normal distribution by Kolmogorov-Smirnov and homogeneity of variances by Levene Test (passed if p<0.05).

Table 1.3. Growth, feed utilization and survival in juvenile Cachama blanca (*Piaractus brachypomus*) fed the experimental diets using macrophytes (DW – duckweed, WF – water fern). Values with the same superscript are not significantly different (p>0.05).

Variables	Diets				
	Control	DW15	DW25	WF15	WF25
Wi (g)	1.57 ± 0.04	1.61 ± 0.03	1.58 ± 0.03	1.61 ± 0.06	1.61 ± 0.11
Wf (g)	11.27 ± 0.65 ^{b}	13.78 ± 0.34 ^{a}	10.90 ± 0.74 ^{b}	13.90 ± 0.46 ^{a}	10.88 ± 1.04 ^{b}
SGR[1] (%/d)	3.29 ± 0.06 ^{b}	3.57 ± 0.03 ^{a}	3.22 ± 0.13 ^{b}	3.59 ± 0.02 ^{a}	3.18 ± 0.13 ^{b}
WG[2] (%)	9.70 ± 0.62 ^{b}	12.17 ± 0.32 ^{a}	9.32 ± 0.75 ^{b}	12.29 ± 0.41 ^{a}	9.26 ± 0.97 ^{b}
FCR[3]	1.19 ± 0.08 ^{ab}	1.06 ± 0.03 ^{a}	1.37 ± 0.16 ^{b}	1.05 ± 0.09 ^{a}	1.34 ± 0.06 ^{b}
PER[4]	2.35 ± 0.17 ^{ab}	2.66 ± 0.07 ^{a}	2.08 ± 0.23 ^{b}	2.78 ± 0.24 ^{a}	2.18 ± 0.10 ^{b}
FC[5] (gfish^{-1})	11.53 ± 0.74	12.91 ± 0.22	12.69 ± 0.63	12.93 ± 1.56	12.34 ± 0.76
SR[6] (%)	94.87 ± 5.88	97.44 ± 2.22	94.87 ± 4.44	94.87 ± 5.88	93.59 ± 4.44

[1] Specific growth rate (SGR) = [lnWf (mean final weight) − lnWi (mean initial weight)/56 days] × 100.
[2] Percent weight gain (WG) = 100(Final weight-Initial weight)/ Initial weight.
[3] Feed conversion ratio (FCR) = total feed intake in dry basis (g) / wet weight gain (g).
[4] Protein efficiency ratio (PER) = total weight gain (g)/protein intake (g).
[5] Feed consumption (FC) during the experimental period (56 days)
[6] Survival Rate (SR)
Wi: initial weight, Wf: final weight

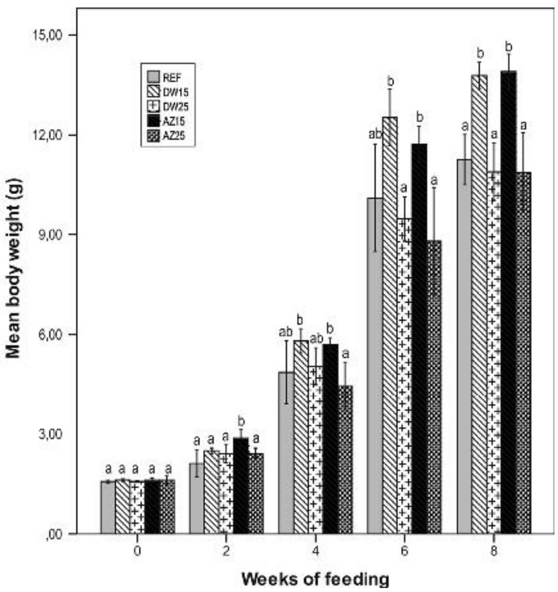

Figure 1. Body weight in juvenile Cachama blanca (*Piaractus brachypomus*) fed the experimental diets using macrophytes (DW – duckweed, WF – water fern). Values with the same superscript are not significantly different (p>0.05).

For multiple comparasion, either parametric Tukey's multiple range or nun-parametric Dunnett's T3 tests were carried out.

Results

Water quality parameters were optimal for Cachama blanca, resulting in a high survival between 94% and 97%. The effect of the diets on growth and feed utilization is shown in Table 1.3. Acceptance of all diets was very good as active, complete consumption were observed and was comparable between treatments.

Results indicate that feed supplementation by the fermented aquatic macrophytes at 15% of inclusion level enhances growth of Cachama blanca fed low fish meal diets. Fish fed DW15 and DW15 diets revealed the highest growth performance, including SGR, final weight and weight gain (P<0.05) compared to the control, DW25 and DW25 diets respectively (Table 1.3). Figure 1 describes growth characteristics in two weeks intervals over the 8 week trial, revealing significant high growth performance for DW15 and WF15, from week 4 on.

The feed utilization, as assessed in FCR and PER, showed no significant differences among DW15, WF15 and the control diet (n=3, P>0.05), but it was significantly higher (P<0.05) than for DW25 and WF25 diets. Congruently, apparent digestibility coefficients (ADC) of dry matter, ash and protein were higher (P>0.05) for DW15, WF15 and the control diet, compared to DW25 and WF25 diets (Table 1.4). And ADC of lipids was significantly higher in the DW25 and DW25 diets compared to the DW15 and DW15 diets.

Discussion

To make the diets isonitrogenous it was necessary to balance the supplementation of 15 or 25% of water plants by alpha cellulose in the experimental diets. As a result the gross energy decreased in the experimental diets from 4 to 7% and the fibre content increased from 40 to 100%. Despite the lower energy concentration of the experimental diets the protein was adequately absorbed and not used as energy source, which is indicated by the significant higher growth in DW15 and WF15 compared to the control. As the content of soluble carbohydrates as energy source was diminished in the experimental diets, the energy need was compensated by an increase in feed intake by aproximately 11% in DW15 and WF15. At the 25% diets the nutrient imbalance cannot be compensated by a higher feed intake.

Table 1.4. Apparent digestibility coefficients (ADC, %) in juvenile Cachama blanca (*Piaractus brachypomus*) fed the experimental diets using macrophytes (DW – duckweed, WF – water fern).Values with the same superscript are not significantly different (p>0.05).

Variables	Diets				
	Control	DW15	DW25	WF15	WF25
ADC_dry matter	93,79 ± 0,39 ^{a}	92,11 ± 1,76 ^{a}	68,89 ± 7,84 ^{b}	93,70 ± 2,28 ^{a}	75,00 ± 5,40 ^{b}
ADC_ash	91,13 ± 0,61 ^{a}	89,09 ± 2,35 ^{a}	45,88 ± 8,54 ^{b}	90,39 ± 3,38 ^{a}	56,12 ± 5,96 ^{b}
ADC_protein	98,34 ± 0,08 ^{a}	98,64 ± 0,28 ^{a}	87,56 ± 3,06 ^{b}	98,33 ± 0,48 ^{a}	88,30 ± 2,78 ^{b}
ADC_lipids	88,37 ± 0,38 ^{b}	88,45 ± 0,09 ^{b}	92,81 ± 0,11 ^{a}	87,49 ± 0,10 ^{c}	88,68 ± 0,42 ^{b}

The SGR reported in this study from 3.2 to 3.6 for diets at 25% and 15% inclusion level, respectively, were comparable to the results reported by Palacios et al. (2006) for Cachama blanca fed a semi-purified diet supplemented at 15% with the Peruvian plants aguaje fruit (3.6), and maca meal (4.1) and higher than those reported for fish fed camu-camu fruit (1.5), which presented a very low SGR. In other study Gaitán-Ibarra (2008) reported also lower SGR for Cachama blanca fed diets supplemented with probiotics and yeast. These results support that fermented aquatic plant supplementation at 15% level into a practical diet increases growth rates and feed efficiency in Cachama blanca.

Fish fed diets containing non-conventional plant material result commonly on poor growth. This is frequently attributed to the presence of antinutrients, low palatability of plant material and the subsequent reduced feed intake. As fermentation process reduced effectively the content of common antinutrients present in the aquatic macrophytes, as we could analyze in an experiment (Cruz *et al.*, 2011), and feed intakes in this study have not differed, the decreased digestibility of dry matter and protein could not be negatively affected by antinutrients but by the higher ash content of each aquatic macrophytes and the 37% increased fibre content in the 25% diets. Similar results have been congruently observed in previous studies on aquatic macrophytes used as feed ingredient for other tropical fish (Bairagi *et al.*, 2002; El-Sayed, 2003, Yilmaz *et al.*, 2004).

Despite of the available protein content of the experimental diets fulfil the requirements of Cachama blanca and to the higher fat content and fat digestibility in the 25% supplementation groups, the reduced availability of nutrients in these diets could not compensate the deficit of energy.

The FCR values from 1.05 to 1.37 in the present study were better than those derived from other alternatives plant sources such as wheat bran, uncooked and cooked yucca, pijuayo, and plantain, which were reported by Lochmann *et al.*, (2009). Gaitán-Ibarra (2008) observed similar FCR values from 1.31 to 2.50 for probiotics and yeast supplemented diets. Better FCR values from 0.64 to 0.68 were only reported by Palacios *et al.*, (2006) for Cachama blanca fed semi-purified diets supplemented with the Peruvian plants maca meal and aguaje fruit, respectively.

The potential variability in the feed utilization parameters between aquatic macrophytes and the Peruvian plants, maca meal and aguaje fruit, may be related to the use of semipurified diets versus the practical ingredient diets in the present study. In their study on digestibility of diet ingredients for Cachama blanca Fernandes *et al.*, (2004) suggested that interactions between diet components are different in semipurified and practical diets and therefore the availability of the nutrients and energy can vary.

Lipids digestibility was higher for diets containing aquatic macrophytes at 25% level. Consequently, it might be due to a lower content of total carbohydrates in DW25 and WF25 diets, then Cachama blanca utilized lipids as energy source for growth. It is consistent with a study in a close relative species Pacu (*P. mesopotamicus*), which is able to utilize lipids as well as carbohydrates to spare protein for somatic growth (Abimorad and Carneiro, 2007). In addition, we also assumed that a dependence between lipids and carbohydrates levels occurred, but further research is needed for confirmation. In general, digestibility coefficients of control and 15% diets were comparable to those reported for common ingredients for pacu (Fernandes *et al.*, 2004).

In conclusion, the utilisation of fermented macrophytes as a cheap, local ingredient for fish feed formulation was feasible up to 15% of inclusion level; thereby their use could support small-scale farming of Cachama blanca in rural zones.

References

Abimorad EG, Carneiro DJ. Digestibility and performance of pacu (*Piaractus mesopotamicus*) juveniles fed diets containing different protein, lipid and carbohydrate levels. Aquac Nutr. 2007; 13: 1-9.

AOAC. 2005. Official methods of analysis of AOAC International. 18th edition. Gaithersburg, MD, USA.

Bairagi A, Sarkar GK, Sen SK, Ray AK. Duckweed (*Lemna polyrhiza*) leaf meal as a source of feedstuff in formulated diets for rohu (*Labeorohita* Ham.) fingerlings after fermentation with a fish intestinal bacterium. Bioresour Technol. 2002;85:17-24.

Brabben T. Research needs for aquatic plant management in developing countries. J Aquat Plant Manag. 1993;31:214-217.

Cruz Y, Kijora C, Wedler E, Danier J, Schulz C. Fermentation Properties and Nutritional Quality of Selected Aquatic Macrophytes as Alternative Fish Feed in Rural Areas of the Neotropics. Livest Res Rural Dev. 2011;23(11): Article 239.

Cruz Y, Kijora C, Torres-Vásquez W, Schulz C. 2011.Dry matter, protein and energy digestibility of selected aquatic macrophytes treated by sun drying and lactic-acid fermentation for the Amazonian fish *Piaractus*brachypomus (Cuvier, 1818). In: *Tropentag Proceedings* 2011. Pp 382.URL: http://www.tropentag.de/2011/abstracts/links/Cruz_AHN0PuE8.php

El-Sayed AFM. Effects of fermentation methods on the nutritive value of water hyacinth for Nile tilapia *Oreochromis niloticus* (L.) fingerlings. Aquaculture. 2003; 218: 471-478.

Flores-Nava A. 2007. Feeds and fertilizers for sustainable aquaculture development: a regional review for Latin America. In: Hasan, MR, Hecht, T, De Silva, SS and Tacon AGJ. (Eds.). Study and analysis of feeds and fertilizers for sustainable aquaculture development.FAO Fisheries Technical Paper.No. 497. Rome, FAO, pp 49-75.

Fernandes JBK, Lochmann R, Alcantara F. Apparent digestible energy and nutrient digestibility coefficients of diet ingredients for pacu Piaractus brachypomus. J World Aquac Soc. 2004; 35(2):237-244.

Furukawa A, Tsukahara H. On the acid digestion method for determination of chromic oxide as an index substance in the study of digestibility of fish feed. Bull Jpn Soc Sci Fish. 1966; 32: 207-217.

Franklin P, Dunbar M, Whitehead P. Flow controls on lowland river macrophytes: A review. Sci *Total* Environ. 2008; 400(1/3): 369-378.

Gaitán-Ibarra SI. 2008. Evaluación del crecimiento de juveniles de Cachama blanca *Piaractus brachypomus* (Cuvier, 1818) utilizando probiótico y levadura. Master's thesis. Universidad del Magdalena. Santa Marta, Colombia.

Lochmann R, Chen R, Chu-Koo F, Camargo W, Kohler C, Kasper C. Effect of carbohydrate-rich alternative feedstuffs on growth, survival, body composition, hematology, and nonspecific immune response of black pacu, *Colossomamacropomum*, and red pacu, *Piaractus brachypomus*. J World Aquac Soc. 2009; 40(1): 33-44.

Nose T. On the digestion of food protein by gold-fish (*Carassiusauratus* L.) and rainbow trout (*Salmoirideus* G.). Bull Freshwater Fish Res Lab. 1960;10:11-22.

Palacios M, Dabrowski K, Abiado M, Lee K, Kohler C. Effect of diets formulated with native Peruvian plants on growth and feeding efficiency of red pacu (*Piaractus brachypomus*) juveniles. J World Aquac Soc. 2006;37(3): 246-255.

Rodriguez L, d Preston TR. Comparative parameters of digestion and N-metabolism in Mong Cai/Large white cross piglets having free access to sugar cane juice and duckweed. Livest Res Rural Dev. 1996; 8:72-81.

Vásquez-Torres W, Yossa M, Hernández G. Coeficientes de digestibilidad aparente de proteína y energía de ingredients de uso común en la elaboración de dietas para Cachama (Avance de Resultados). Revista de la Facultad de Medicina Veterinaria y de Zootecnia. 2007; 54(2):67-250.

Erdal Yilmaz E, Akyurt I, Gökhan Günal G. Use of Duckweed, *Lemna minor*, as a Protein Feedstuff in Practical Diets for Common Carp, *Cyprinus carpio*, Fry. Turk J Fish Aquat Sci. 2004; 4:105-109.