Processing yield and meat quality of cachara *Pseudoplatystoma reticulatum* and hybrid cachapinta *P. reticulatum* × *P. corruscans*

Leticia Fantini-Hoag\(^a,b\), Ruy Alberto Caetano Corrêa Filho\(^b\), Jorge Antonio Ferreira Lara\(^c\), Jovana Silva Garbelini\(^d\), Jonathan Coimbra Carvalho\(^b\), Antonio Francisco Oliveira\(^b\), Cristiane Meldau de Campos\(^b,d\), Terry Hanson\(^a\) and Jayme Aparecido Povh\(^b\)

\(^a\)School of Fisheries, Aquaculture and Aquatic Sciences, Auburn University, Auburn, AL, USA; \(^b\)Animal Science Graduate Program, Federal University of Mato Grosso do Sul – UFMS, Campo Grande, Brazil; \(^c\)Brazilian Agricultural Research Corporation, Pantanal Research Center, Corumbá, Brazil; \(^d\)Animal Science program, State University of Mato Grosso of Sul (UEMS), Aquidauana, MS, Brazil

**ABSTRACT**

Hybrid cachapinta (*Pseudoplatystoma reticulatum* × *Pseudoplatystoma corruscans*) has been a very popular fish and is well accepted by consumers internationally, however, there is a lack of information showing its advantages relative to its parental cachara (*P. reticulatum*) species. This study was undertaken to compare the processing yield and meat quality characteristics of cachara and the cachapinta hybrid raised in net cages. Cachara’s weight was 1.51 ± 0.27 kg and total length was 49.85 ± 6.22 cm at harvest and was not significantly different from hybrid cachapinta that weighed 1.50 ± 0.11 kg and measured 50.83 ± 3.91 cm. Additionally, the two groups were not statistically different on gutted fish dress out (cachara: 89.97 ± 1.28%; cachapinta: 90.23 ± 0.30%) and other processing yield parameters. Skinless shank fillets with an average weight of 503.77 ± 0.10 g (cachara) and 514.41 ± 0.04 g, (hybrid cachapinta) were evaluated for pH, water holding capacity, colour (\(L^*, a^*, b^*\)), shear force and lipid oxidation (TBARS). There were no differences in the fillet meat quality between cachara and hybrid cachapinta tested in this study. In conclusion, both genetic groups had similar processing yield and fillet meat quality characteristics when produced in net cages.

**HIGHLIGHTS**

- The perceived improvements in growth and disease-resistance generated by hybrid vigour are the main reasons for interest and use of hybrid fishes.
- It is difficult to systematically predict processing yield and meat quality obtained from hybrids.
- Processing yields and meat quality are similar for cachara and hybrid cachapinta produced in net cages.

**ARTICLE HISTORY**

Received 25 May 2021
Revised 6 January 2022
Accepted 1 April 2022

**KEYWORDS**

Fillet; hybrid fish; siluriformes

**Introduction**

Freshwater fish, such as Siluriformes (including *Pangasius* spp.) are of great economic importance to the aquaculture world (FAO 2018, 2020). The most common siluriformes used in aquaculture in South America belong to the family Pimelodidae, and the genera *Pseudoplatystoma, Phractocephalus,* and *Leiarius* (Hashimoto et al. 2012). In Brazil, the surubim (cachara *Pseudoplatystoma reticulatum*, pintado *Pseudoplatystoma corruscans*, and hybrids) are the species of greatest economic importance.

Hybrids generated by crosses between ♀ *Pseudoplatystoma reticulatum* × ♂ *Pseudoplatystoma corruscans*, popularly known as cachapinta, were the first interspecific catfish hybrids produced commercially for aquaculture; and their production volume exceeded that of their pure parental species in Brazil (Hashimoto et al. 2012). Hybrid fishes are produced for several reasons such as consumer demand and improvement in characteristics generated by hybrid vigour (Bartley et al. 2000). Hybridisation may also be used to transfer other desirable characteristics from one group or species to another, or to combine valuable traits from two species into a single group (e.g. good growth or flesh quality) (Bartley et al. 2000).

The superior performance or desirable characteristics associated with hybrid vigour may be lost in post-F1 individuals because introgressive hybridisation reduces the amount of heterosis obtained in F1
hybrids (Hashimoto et al. 2012). It is unknown if the processing yields and meat characteristics of hybrids and pure individuals in a simulated commercial production setting are different. The potential of surubim (pure and hybrid) for aquaculture lies mainly in the excellent quality of its meat, absence of intramuscular bones and rapid growth (Moro et al. 2013). Fillet yields reported in the literature for surubim range from 40.16%, raised in ponds (Fantini et al. 2013) to 47.79% raised in cages (Burkert et al. 2008). The objective of this study is to compare the processing yield and meat quality of cachara and the hybrid cachapinta reared in net cages.

Material and methods

Location and experimental design

The experiment was conducted in net cages at a fish farm located in Brazil (21°27’51” S and 54°23’3” W). Fingerlings of cachara (P. reticulatum) and hybrid cachapinta (cross between cachara [P. reticulatum] females and pintado [P. corruscans] males) were acquired from a local commercial business. The experiment was set up as a completely randomised design with two treatments (cachara and cachapinta) and three replicates for each treatment. Fingerlings were stocked in 20 mm mesh net cages (13.5 m³) spaced 2 m apart from each other. The total experimental period was 216 days, from July to March 2015.

A total of 144 cachara fish with an average weight of 75.00 ± 0.004 g were stocked in each net cage, while 127 cachapinta hybrids with an average weight of 85.00 ± 0.006 g were stocked per net cage. The different numbers of fish for each group were established so that the trial would begin with fish biomass of 10.8 kg per net cage. The procedures adopted in this study were approved by the Animal Use Ethics Committee (CEUA/Federal University of Mato Grosso do Sul-UFMS; approval no. 642/2014).

Feeding

Fish were fed with commercial floating feed twice daily between 7 am to 8 am, and 5 pm to 6 pm throughout the trials. The amount of feed was based on the total biomass in each net cage. Feeding was adjusted after weight sampling of each cage every 45 days and the new feeding rate was based on a decreasing percentage of biomass, starting at 8% and ending at 3%. Fish weighing <800 g were fed 2–9 mm pellets and fed 4–8% of their biomass depending on their size. Their feed had 40% crude protein, 9–11% ether extract, 2.5–2.8% crude fibre, 10–14% mineral matter, and 88% dry matter. Fish weighing >800 g received 13–15 mm pellets and were fed 3% of their biomass. Their feed was 38% crude protein, 9% ether extract, 3.2% crude fibre, 12.5% mineral matter, and 88% dry matter.

Water quality

Water samples were collected monthly from the production site at a depth of 50 cm at three points near the net cages. Alkalinity, hardness, and total ammonia were evaluated by standard methods (APHA/AWWA/WEF 2012). Temperature, dissolved oxygen, and pH of the water were measured using a YSI ProPlus multi-parameter instrument. The mean values (±standard deviation) of temperature, dissolved oxygen, pH and total ammonia in the water during the months of production were 25.80 ± 1.62 °C, 7.87 ± 0.18 mg L⁻¹, 7.39 ± 0.24 and 0.11 ± 0.01 mg L⁻¹, respectively. These water characteristics are within the recommended ranges for fish production (Boyd 1998). The total alkalinity (15.02 ± 1.48 mg/L) and total hardness (14.96 ± 0.95 mg/L) of the water were slightly below the recommended values suggested by Boyd (1998), but common for large natural water bodies (Boyd and Tucker 1998).

Processing yield

After 216 days of production, cachara and hybrid cachapinta were taken off feed for 48 h to empty their gastrointestinal system. 9 fish were sampled from each replicate, 27 fish in total from each treatment, with a mean total weight of 1.51 ± 0.27 kg and 1.50 ± 0.11 kg for cachara and hybrid cachapinta, respectively. All 54 sample fish were sacrificed by thermal shock on ice. Fish were processed by hand by a single trained employee from a local processing plant.

Fish were eviscerated (gutted) and viscera were removed and weighed. From the gutted fish, the head and fins were removed, and the resulting product was used for obtaining fillets. To obtain shank fillets, dorsolateral muscles were cut lengthwise, along the entire spine, from the cranial region to the end of the caudal peduncle. Abdominal fillets (or nuggets) were sectioned from the region near the base of the pectoral fins towards the base of the ribs, then the skin was removed from both fillets, as recommended by Burkert et al. (2008). The remaining fish carcase included the skeletal frame and fins removed earlier (leftover), and they were discarded after being weighed. Processing yields were determined...
as a percentage relative to the whole fish’s body weight (after being euthanised).

**Fillets meat quality**

Skinless shank fillets of cachara and hybrid cachapinta, with a mean weight of 503.77 ± 0.10 g and 514.41 ± 0.04 g, respectively, were frozen at −20°C to evaluate pH, water holding capacity, colour, shear force and lipid oxidation. For the analysis, skinless shank fillet samples were thawed at a temperature of 7°C in the refrigerator for about 12 h. For each variable, three unique points were sampled on each fillet, except colour which was taken at six points (Figure 1).

Deep intramuscular pH was determined before performing other tests (Figure 1(a)) (measured post-mortem at 48 h). A Mettler Toledo® (model 1140, São Paulo, Brazil) pH metre with a specific electrode for meat was used. Colour values (Hunter system) of L* (brightness), a* (redness-greenness), and b* (yellowness-blueness) of the fillets were assessed using a colorimeter Minolta Camera (model CR-10, Ltd., Osaka, Japan) at an angle of 90° (Figure 1(b)).

Water holding capacity (WHC) was calculated as weight after centrifugation (g) – weight after drying (g)/initial weight (g) × 100 (Nakamura and Katoh 1985). Shear force (SF) was calculated using a TAXT2® (Texture Extralab®, Jarinu, SP, Brazil) expressed in kilogram-force kgf. Twenty-seven skinless fillets were used for each genetic group; three samples were taken from each fillet (Figure 1(d)), totalling 81 sub-samples of cachara and hybrid cachapinta. Lipid oxidation was assessed using the thiobarbituric acid-reactive substances (TBARS) method described by Vyncke (1970), with modifications.

**Statistical analysis**

The analyses were conducted using the Statistical Analysis System (SAS 2016). Data were tested for homogeneity of variance using Levene’s test (PROC GLM) and normality using the Shapiro-Wilk test (PROC UNIVARIATE). Processing yield and meat quality characteristics of cachara and hybrid cachapinta were subjected to an unpaired t-test using analysis of variance (ANOVA – PROC GLM Procedure).

**Results and discussion**

Total and partial lengths, along with whole body weights were not different between cachara and hybrid cachapinta tested in this study (Table 1). Likewise, there were no statistical differences in processing yields (gutted fish, carcass, shank fillets with
Table 1. Mean values ± standard deviation of the total length, partial length, whole body weight at harvest and processing yield of cachara (Pseudoplatystoma reticulatum) and hybrid cachapinta (Pseudoplatystoma reticulatum × Pseudoplatystoma corruscans) produced in net cages.

| Parameters                      | Genetics groups          |
|---------------------------------|--------------------------|
|                                 | Cachara/C3               | Hybrid cachapinta/C3 |
| Total final length, cm          | 49.85 ± 6.22             | 50.83 ± 3.91         |
| Partial final length, cm        | 43.10 ± 5.15             | 43.31 ± 2.29         |
| Whole body weight at harvest, kg| 1.52 ± 0.27              | 1.50 ± 0.11          |
| Guttered fish, %                | 89.97 ± 1.28             | 90.23 ± 0.30         |
| Carcase, %                      | 68.72 ± 1.42             | 70.03 ± 0.42         |
| Shank fillets with skin, %      | 37.98 ± 0.36             | 38.88 ± 0.38         |
| Skinless shank fillets, %       | 33.18 ± 1.24             | 34.26 ± 0.54         |
| Nuggets with skin, %            | 14.92 ± 0.30             | 15.28 ± 0.25         |
| Nuggets without skin, %         | 13.63 ± 1.02             | 12.88 ± 0.16         |
| Shank + Nuggets without skin, % | 46.81 ± 1.56             | 47.14 ± 0.53         |
| Head, %                         | 20.38 ± 0.90             | 20.05 ± 0.25         |
| Skin, %                         | 6.79 ± 0.59              | 7.14 ± 0.21          |
| Viscera, %                      | 7.20 ± 0.20              | 6.15 ± 0.03          |
| Leftover, %                     | 18.80 ± 0.31             | 18.58 ± 0.46         |

There were no significant differences between genetics groups (t-test, p > .05).

skin, skinless shank fillets, nuggets with skin, skinless nuggets, skinless shank + nuggets, head, skin, viscera, leftover) between cachara and hybrid cachapinta when produced in net cages (Table 1).

Although surubins have not been part of genetic improvement programs to date (Fantini et al. 2013), the potential to increase yields could be researched. In our study, the carcase (dress-out) percentage was 68.72 ± 1.42% for cachara and 70.03 ± 0.42% for the hybrid cachapinta. This was similar to the results found, for hybrid cachapinta (69.93 ± 1.61%) produced in ponds under different stocking densities (Fantini et al. 2014), also for Pseudoplatystoma spp. produced in net cages (70.45 ± 1.64%), and Pseudoplatystoma spp. produced in ponds (69.97 ± 1.78%) (Fantini et al. 2013). From the carcase (dress-out) originates the fillet which is a valuable cut for consumers (Carneiro et al. 2004).

Fillets’ yield ranges for surubins (cachara, pintado and their hybrids) vary widely. Skinless shank fillet yields were 33.18 ± 1.24% and 34.26 ± 0.54%, and nugget yields were 13.63 ± 1.02% and 12.88 ± 0.16% for cachara and hybrid cachapinta, respectively. Carneiro et al. (2004) obtained values of 34.75% and 11.22% for cachara and hybrid cachapinta, respectively. Carneiro et al. (2004) obtained values of 34.75% and 11.22% for skinless shank fillet and nugget, respectively for jundia Rhamdia quelen produced in ponds. The strain of channel catfish studied by Li et al. (2004) had a fillet yield of 38.6% and nugget yield of 9.6% while the catfish hybrid had 38.4% and 10.6% yields respectively. When shank and nugget yield percentages are combined, our surubins raised in cages had fillet yields of 46.81% for cachara and 47.14% for hybrid cachapinta. This was better than 40.16% for Pseudoplatystoma spp. raised in ponds (Fantini et al. 2013) and similar to 47.79% for the Pseudoplatystoma spp. raised in cages (Burkert et al. 2008). Hybrid catfish (Pseudoplatystoma reticulatum × Leiarius marmoratus) raised in ponds fed with feeds containing 32% or 40% crude protein had yields of 46.27 ± 0.86% and 47.12 ± 0.76, respectively (Souza et al. 2017). These differences in processing yields can be due to several factors, such as sex, size or age, operator dexterity, filleting method, degree of mechanisation and other species characteristics (Macedo-Viegas and Souza 2004).

Although hybrids may provide heterosis in certain conditions, expressing better development than the parental populations (Bartley et al. 2000), this was not the case in this study. This could be due to our study’s single fish production crop, which was enough to achieve the fish size suitable for the Brazilian market. Catfish are processed at 1.2 kg in Brazil which can be achieved in 8–10 months (Frascâ-Scorvo et al. 2008), while in the US catfish production may take longer than a year, 11–17 months (Creel et al. 2021), and are processed at 1–1.8 kg.

The fish meat quality can be affected by many factors: stressful events, which may include environmental conditions, harvesting and transport from pond to processor (Bosworth et al. 2004; Refaey et al. 2017), temperature (Arnold et al. 2013), feed composition (Li et al. 2007), pre-slaughter (Goes et al. 2019) as well as disease (Allred et al. 2019). Flesh colour is one of the first quality attributes used by consumers to evaluate the quality of a product (meat, fish, vegetables and fruits) (Tijskens et al. 2001).

No significant effect of the genetic group was found on meat quality characteristics (Table 2). The present study had fillets with lower L* compared with that considered acceptable for the US catfish industry.
65.5 (± 0.4) reported by Allred et al. (2019) but similar to surubins (Pseudoplatystoma spp.) produced in ponds (48.73) and in cages (49.09) (Fantini et al. 2014). Comparing our study results with fresh fillets of Nile tilapia, Oreochromis niloticus, for example, we saw similar values of L* (brightness) and higher values of a* (redness-greenness) and b* (yellowness-blueness) (L* = 43.43; a* = −3.80; b* = 0.29) (Zhao et al. 2017). While salmon has lower L* (40.6) and higher a* (10.5) and b* (13.6) values compared with surubins (Erikson and Misimi 2008). The salmon industry has well-established colour standards, which have been used as a reference for the colour standard development in the catfish industry (Roche SalmoFan™) (Cline 2011; Hu et al. 2017). However, research on meat quality properties of Brazilian fish is still in its beginning stages and does not yet have any developed procedures or colour standards established.

Muscle pH has been associated with numerous other meat quality attributes including tenderness, water holding capacity, cooking loss, and microbial stability (Fletcher 2002). Brazilian law established a maximum pH value for fresh fish fillets of 7.0 if its sensory characteristics are to be fully preserved (Brasil Ministério da Agricultura, Pecuária e Abastecimento 2017). In the current study, cachara had a pH after freezing of 6.62 ± 0.01 and the hybrid cachapinta had a pH after freezing of 6.59 ± 0.13. Those values are similar to the Allred et al. (2019) catfish study, where the U.S. catfish industry had acceptable fillets with a pH of 6.43 ± 0.06 (measured at 24 h post-mortem). A previous hybrid surubim study showed there were fillet pH differences when fish were produced in cages and ponds. Fish produced in ponds had higher pH levels (6.39 ± 0.10) than in cages (6.17 ± 0.23) and this was found to affect the shear force (Fantini et al. 2014). Since high pH meat loses less drip and suffers less cooking loss, shrinkage of the meat during preparation, shear force measurements are reduced, which would translate into fewer fibres in a given cross-sectional area of meat and, thus less of the structural elements responsible for toughness (Watanabe et al. 1996).

Spoilage of fish occurs concurrently and independently, with relative importance factors varying with species of fish (size, lipid content, maturation stage, etc.), environmental conditions (feeding availability, temperature, microbial load, etc.), method of slaughter, post-mortem handling, storage procedures and processing conditions (Medina et al. 2009). Lipid oxidation was measured by the acid method thiobarbituric (TBARS) and acts as a lipid peroxidation biomarker and impairs the sensory quality of meat products in general. Our results showed low values of malondialdehyde kg⁻¹, an indication of no rancidity in storage at −20°C. In the present study, both environment and diet were the same for all evaluated genetic groups which might be the cause of the non-difference.

Surubim catfish shear force was lower (Table 2) compared with Atlantic seabob prawn meat (0.67 ± 0.10 kgf), and to the surubim catfish fillet produced in cages (1.06 ± 0.22 kgf), and produced in ponds (0.78 ± 0.17 kgf) (Fantini et al. 2015). The higher the force dispersed, the lower the tenderness of the fillets, which reflects a higher tenderness of fillets obtained in this surubim study. Pork and poultry meats have less tenderness compared with fish meat that originated from aquaculture (Fantini et al. 2015). This feature is just one of the positive aspects that can be highlighted in the advertising and marketing of fish meat, which can result in increased consumption.

**Conclusion**

These results indicate that processing yield, such as fillet yield, and meat quality characteristics did not differ between hybrid cachapinta and pure cachara. The data can be used as comparative parameters for future studies with Siluriformes under production conditions (e.g. nutrition and production system), genetic programs (e.g. hybrids and genetic improvement), and processing attributes.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**Funding**

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (Fundeect) and Universidade Federal de Mato Grosso do Sul (UFMS/MEC - Brazil).

**Data availability statement**

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

**References**

Allred S, Shao W, Schilling MW, Petrie-Hanson L, Allen PJ. 2019. An assessment of red fillet prevalence in the catfish industry. Aquaculture. 507:878–210.
subjected to different protein levels. Bol Inst Pesca. 43: 113–120.

Tijskens LMM, Barringer SA, Biekman ESA. 2001. Modelling the effect of pH on the colour degradation of blanched broccoli. Innov Food Sci Emerging Technol. 2(4):315–322.

Vyncke W. 1970. Direct determination of the thiobarbituric acid value in trichloracetic acid extracts of fish as a measure of oxidative rancidity. Fette, Seifen, Anstrichm. 72(12):1084–1087.

Watanabe A, Daly CC, Devine CE. 1996. The effects of the ultimate pH of meat on tenderness changes during ageing. Meat Sci. 42(1):67–78.

Zhao Y, Yang X, Li L, Hao S, Wei Y, Cen J, Lin H. 2017. Chemical, microbiological, color and textural changes in Nile tilapia (Oreochromis niloticus) fillets sterilized by ozonated water pretreatment during frozen storage. J Food Process Preserv. 41(1):e12746.