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Comparison of Growth, Body Composition, and Stress Responses of USDA103, USDA403, Industry, and Fast Growing Lines of Channel Catfish

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Production traits such as growth, feed efficiency, survival, and fillet yield are economically important traits and an improvement in one or more of these traits will benefit the U.S. catfish farming industry. The U.S. Department of Agriculture (USDA) 103 line of channel catfish was developed jointly between the USDA Agricultural Research Service (ARS) Catfish Genetics Research Unit, Stoneville, Mississippi, and the Mississippi Agricultural and Forestry Experiment Station, Thad Cochran National Warmwater Aquaculture Center (NWAC), Stoneville. The USDA103 line of catfish (also referred to as the NWAC103 line) is being selected for increased growth, fillet yield, and resistance to enteric septicemia of catfish (ESC) and being compared with other genetic groups of catfish having potential commercial use.

The USDA103 strain was developed from broodfish obtained in 1992 from the Uvalde National Fish Hatchery, Uvalde, Texas, USA. Many studies have compared growth rates of the USDA103 with other strains of channel catfish and have found that the USDA103 channel catfish exhibit superior growth characteristics (Silverstein et al. 1999; Wolters et al. 2000; Li et al. 2001; Jackson et al. 2003; Bosworth et al. 2004a; Peterson and Small 2006). The faster growth of the USDA103 strain of channel catfish is typically attributed to their ability to consume more feed (Li et al. 2001).

The USDA103 strain has been selected for two generations for improved growth, fillet yield, and resistance to ESC to produce the USDA303 strain. Three studies have compared the growth of the USDA103 to the USDA303 line. Using a recirculating aquarium rack system (23-L tanks), Small (2006) reported a 21% improvement in growth of the USDA303 strain over the USDA103 strain of catfish while feed efficiency was similar. Using 110-L flow-through aquaria, Li et al. (2006) found marginal improvements in final weight (5.1%) and feed efficiency (3.3%) for the USDA303 strain compared with the USDA103 strain. Using 76-L flow-through aquaria, Peterson et al. (2008b) found no significant improvement in weight gain or feed efficiency in a growth study comparing these two lines. It is not clear from these studies if the improved growth of the USDA303 strain reported in some studies is because of environment or genetics.

Using an aquaria challenge model, improvements in resistance to ESC have also been reported for the USDA303 strain compared with the USDA103 strain (Bilodeau et al. 2007; Peterson et al. 2008b). Conversely, recent meat yield studies showed that fillet yield between these two strains were similar (B. Bosworth, not published). The apparent improvement of growth and resistance to ESC will need to be further evaluated in a pond environment.

As part of our selective breeding program, we recently obtained spawns from eight different farms across the Mississippi Delta. Our goal is to evaluate these fish for growth, fillet yield, and resistance to ESC and compare these results to strains such as the USDA103 line of catfish. It is possible that crossing USDA103 lines of catfish with fish obtained from catfish farms

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will produce fish with desirable growth, meat yield, reproductive, and disease characteristics.

The purpose of this study was to compare the USDA103 line of channel catfish, the USDA403 (USDA103 selected for three generations), a fast growing line of catfish (USDA103 line selected for fast growth for one generation), and an industry pool line of catfish (three spawns collected from three different catfish farms) for growth, body composition, and stress responses.

Materials and Methods

Source of Fish

Four genetic groups of channel catfish were compared for growth, body composition, and stress response. The USDA103 strain was described above and is maintained at the Catfish Genetics Research Unit, Stoneville, Mississippi, USA. Continued selection of the USDA103 strain for growth, fillet yield, and disease resistance to ESC for three generations produced the USDA403 line. The industry pool group of fish was obtained from three spawns that were collected from three different catfish farms across the Mississippi Delta. The fast-growing strain of fish was obtained by selecting the USDA103 line for fast growth only for one generation.

All fish were reared in indoor 151-L aquaria in a common environment (water temperature ca 26.6 C, diel light : dark cycle = 14 h : 10 h, pH $\sim$ 8.5, and dissolved oxygen levels $>$5.0 mg/L) under common feeding conditions prior to stocking. Each genetic group was composed of fish from three spawns (ca 30 fish/spawn). These pooled fish from each of the genetic groups were placed in four separate 151-L tanks prior to stocking. Spawns from each of the genetic groups were chosen based on the day of hatch. All spawns were hatched no greater than 11 days apart.

Growth Study

Seventy-five catfish from each group were randomly stocked (15 fish /tank) into each of 20, 76-L flow-through aquaria (five replicates/group) and allowed to acclimate for 10 days. After the acclimation period, fish were anesthetized with 0.1 g/L tricainemethane sulfonate (MS-222; Western Chemical Inc., Ferndale, WA, USA), individually weighed to the nearest 0.1 g and measured for length. The fast growth catfish averaged 14.6 ± 0.1 g (mean $\pm$ SEM) per fish while the USDA403, USDA103, and industry pool averaged 10.4 ± 0.2, 10.6 ± 0.3, and 6.9 ± 0.3 g, respectively. Three fish from each tank (15 fish/group) were randomly euthanized (0.3 g/L MS-222) and then frozen at -20 C for subsequent proximate analysis and bomb calorimetry.

The aquaria were supplied with flow-through well water (7.5 L/min) and continuous aeration. Water temperature averaged 26.7 ± 0.2 C and a diel light : dark cycle was set at 14 h : 10 h. Water quality (pH $\sim$8.5 and dissolved oxygen levels $>$5.0 mg/L) was similar between tanks. The fish were fed to visual satiety once a day between 0800 and 0900 hours. Visual satiety was achieved by feeding all the feed the fish would consume in 20 min. Fish from the four groups were offered a commercial 36% crude protein (Melick Aquafeed Inc., Catawissa, PA) floating catfish diet (1.5 mm) and the amount was weighed daily. No mortalities were observed during the 8-wk study. On Weeks 4 and 8 of the study, fish were handled and measured as previously described. On Week 8, three fish from each tank (15 fish/group) were randomly euthanized with an overdose of MS-222 and then frozen at -20 C for subsequent analysis.

Because the initial weights of the four genetic groups were different at the time of stocking, a growth rate index suggested by Jobling (1983) and modified for channel catfish by Silverstein et al. (1999) was used to compare growth rates. The growth index a was calculated as $\log_e G_w = a - 0.371 \log_e W_m$ where $G_w = (\ln W_2 - \ln W_1)100/t$, where W_2 is the weight at the end of the growth interval, W_1 is the weight at the beginning growth interval, and t is the number of days in the interval (56). W_m was calculated as the mean tank weight at the start of the experiment + the mean tank weight at the end of the experiment/2. The intercept (a) allows the comparison of

growth rate at unit size and has been suggested as an appropriate method for comparing the growth of fish with different initial weights (Jobling 1983; Silverstein et al. 1999). Weight gain (average amount of weight gained (g) per fish over the 8-wk study), feed intake (average amount food (g) consumed per fish over the 8-wk study), feed conversion ratio (FCR = ingested food (g)/weight gain (g), and condition factor (K = final weight (g)/[length $(cm)^3$] $\times$ 100) were also calculated.

Three fish from each aquaria from each of the two sampling periods (Day 0 and Week 8) were pooled together, minced in a grinder, freeze dried (Virtis Unitop 800 L, Gardiner, NY, USA), reground; and crude protein, fat, moisture, and ash were determined in duplicate by methods described by the Association of Official Analytical Chemists International (1995). Bomb calorimetry was conducted using an adiabatic bomb calorimeter (Parr 1710, Parr Instruments Co., Moline, IL, USA).

In addition to the proximate components, energy retention (ER), protein efficiency ratio (PER), and nitrogen retention (NR) were determined. ER was calculated using the formula: $wt \times et - wi \times ei)/fi \times e$, where wt = weight at the end of a sampling period, wi = initial weight, fi = feed intake, and e, et, and ei = energy content of the diet, fish at termination, and fish at initiation of study, respectively. PER was calculated using the formula: amount of weight gained (g)/protein consumed (g) and NR was calculated using the formula: retained nitrogen (g)/nitrogen consumed (g) $\times$ 100.

One week after the 8-wk growth study, the remaining fish (9/tank) were subjected to an acute confinement stressor. The stress was accomplished by total removal of the water from each aquarium. The volume of water was drained in approximately 3 min and held for 10 min. Nine fish per tank were anesthetized with 6 mg/L metomidate hydrochloride and bled from the caudal vasculature into syringes coated with heparin. Three people bled the fish and the amount of time it took from anesthetizing the fish until they were all bled was approximately 3 min. Metomidate hydrochloride was used as it blocks the handling-related release of cortisol into circulation, minimizing endogenous plasma cortisol variability because of sampling (Small and Davis 2003). The plasma was separated and frozen at −20 C.

Cortisol Determination

Cortisol was measured using a DELFIA® time-resolved fluroimmunoassay kit (Perkin-Elmer Life Sciences, Boston, MA, USA). This kit has been validated for the quantification of plasma cortisol in channel catfish (Small and Davis 2003).

Data Analysis

Statistical analyses were conducted using the mixed procedure of the Statistical Analysis System (SAS, Version 9.1 software). Weight gain, *a*, feed intake, FCR, K, ER, PER, NR, and cortisol levels were subjected to one-way analyses of variance (ANOVAs) with strain as a fixed effect and tank within strain as a random effect. Body composition indices were subjected to one-way ANOVAs containing strain as the fixed effect, tank within strain as the random effect, and final weight as a covariate. Tank served as the experimental unit for each variable measured. Differences among genetic lines were considered significantly different at $P < 0.05$.

Results

By Week 4, feed intake and weight gain were significantly different for each genetic group ($P < 0.0001$). Four-week weight gains were 23.8 ± 1.4, 18.5 ± 1.2, 15.8 ± 0.7, and 10.4 ± 0.2 g/fish while feed intakes were 26.2 ± 1.0, 20.2 ± 0.9, 17.6 ± 0.4, and 11.8 ± 0.2 g/fish for the fast growing, USDA403, USDA103, and industry pool, respectively. Overall, fast growing, USDA403, and USDA103 genetic groups consumed more feed, gained more weight, and had a higher growth rate index *a* than industry pool fish ($P < 0.01$) (Table 1). In addition, fast-growing fish gained more weight and consumed more feed than the other three lines of catfish ($P < 0.001$). FCR was lower in the fast-growing fish compared with the USDA103 fish but was similar to the

other genetic groups ($P < 0.05$). Differences in weight to length ratios were reflected in the condition factor-values (K) of the four genetic groups of fish with the industry pool having the lowest K-value. Plasma cortisol levels were not different among the four genetic lines after they were subjected to an acute 10-min confinement stressor.

The amount of whole body fat, protein, and ash were similar among strains when final weight was used as a covariate ($P > 0.05$) (Table 2). Fast growth, USDA403, and USDA103 lines had higher ($P < 0.05$) PERs compared to industry pool. The actual retention of nitrogen from consumed protein and ER was similar ($P > 0.05$) among genetic groups.

Discussion

We examined growth performance and whole body composition indices in four genetic groups of channel catfish. The USDA line of catfish (fast growth, USDA403, USDA103) was larger at stocking and at the end of the 8-wk study compared to the industry pool. Because of the early growth advantage of the USDA103 line observed in the current study and reported by others (Silverstein et al. 1999; Bosworth et al. 2004a), adjustments were made for differences in starting weights using a growth rate index a. Adjustments for differences in starting weights can be problematic and misleading if fish with faster early growth are penalized for the superior early growth (Hopkins 1992). In the present study, all genetic lines were reared under similar hatchery conditions, feeding rates, and hatching dates. Therefore, the initial size differences appear to have a genetic basis. In addition, USDA103 channel catfish lines typically have superior early growth compared with other catfish lines in both pond and tank trials (Li et al. 1998; Li et al. 2001; Bosworth et al. 2004; Small 2006; Peterson et al. 2008b).

The present studied showed by Week 4 that feed intake and weight gain were significantly different for each genetic group. However, the difference in intake and weight gain was not realized among all genetic lines at the end of the 8-wk study. At termination of the trial, feed consumption, weight gain, and growth rate index a were highest in the fast growing line of fish. The fast-growing fish also had a lower (improved) FCR compared to the USDA103 strain but was not statistically different from the USDA403 or industry pool. The small but significant improvement in FCR in the fast-growing fish compared to the USDA103 line was unexpected and further studies will need to be conducted to verify this apparent difference.

This is the first study to compare the USDA403 line of catfish to the USDA103 line

TABLE 1. *Weight gain, growth rate index* a*, feed intake, feed conversion ratio (FCR), condition factor (K), and cortisol levels of four genetic lines of channel catfish.*

Strain	Weight gain (g)[a]	a[b]	Feed intake (g)[c]	FCR[d]	K[e]	Cortisol[f] (ng/mL)
Fast growth	47.5[x]	1.00[x]	57.2[x]	1.21[x]	.79[x]	58.1
USDA403	35.0[y]	0.96[y]	44.0[y]	1.26[xy]	.74[y]	51.4
USDA103	33.1[y]	0.94[y]	42.9[y]	1.30[y]	.76[y]	62.4
Industry pool	22.5[z]	0.88[z]	27.8[z]	1.24[xy]	.69[z]	60.2
SE[g]	0.84	0.00	0.81	0.01	0.00	1.64

[a]Mean initial weight was 27.7 g/fish.

[b]a is a growth index defined as $\log_e G_w = a - 0.371 \log_e W_m$ where $G_w = (\ln W_2 - \ln W_1)100/t$, where W_2 is the weight at the end of the growth interval, W_1 is the weight at the beginning growth interval, and t is the number of days in the interval (56). W_m was calculated as the mean tank weight at the start of the experiment + the mean tank weight at the end of the experiment/2.

[c]Feed intake represents the average amount food (g) consumed per fish.

[d]FCRs were calculated as ingested food (g)/ weight gain (g).

[e]K represents final weight (g)/[length $(cm)^3$] $\times$ 100.

[f]Plasma levels of cortisol (ng/mL) after an acute 10 min. confinement stress. Sample size was $n = 5$ (3 fish/tank).

[g]SE is the pooled standard error of the mean.

[x,y,z]Within columns, values with different letters are different ($P < 0.05$).

TABLE 2. *Least-squares means for whole body composition indices (dry-weight basis), energy retention (ER), protein efficiency ratio (PER), and nitrogen retention (NR) of four genetic lines of channel catfish.*

Strain	Fat (%)	Protein (%)	Ash (%)	ER (%)[a]	PER[b]	NR (%)[c]
Fast growth	38.0	53.0	8.7	1.2	2.2[x]	42.6
USDA403	31.1	60.1	8.7	1.1	2.2[x]	44.1
USDA103	35.0	55.6	9.3	1.1	2.2[x]	43.8
Industry pool	36.0	54.7	9.6	1.1	2.0[y]	40.9
SE	0.9	3.4	0.2	0.0	0.0	8.2

[a]Enery Retention was calculated using the formula: $(wt \times et - wi \times ei)/fi \times e$, where wt = weight at the end of a sampling period, wi = initial weight, fi = feed intake, and e, et, and ei = energy content of the diet, fish at termination, and fish at initiation of study, respectively.

[b]PER was calculated as the amount of weight gained (g)/protein consumed (g).

[c]NR was calculated as retained nitrogen (g)/nitrogen consumed (g) × 100.

[x,y]Within columns, values with different letters are different ($P < 0.01$)

of catfish. After three generations of selecting the USDA103 line for improved growth, fillet yield, and resistance to *Edwardsiella ictaluri*, our results showed no improvement in growth or FCR between the two genetic groups. There are possible explanations to why there was no observed improvement in growth between the groups. One, the USDA403 line used in the study was pooled from only three spawns. Perhaps three spawns are not representative on the genetic potential of USDA403 catfish. Two, genetic improvement is slower when selection is made for more than one trait at a time. In support of this argument, selecting the USDA103 line only for fast growth produced a faster growing line of fish (fast-growing genetic group). It is possible that it will take many more generation intervals to realize genetic improvements in growth, fillet yield, and resistance to *E. ictaluri*.

Other studies have compared the USDA303 strain (USDA103 strain selected for growth, fillet yield, and resistance to *E. ictaluri* for two generations) to the USDA103 line and the results have been variable. For example, in a recirculating aquarium rack system, Small (2006) reported a 21% improvement in growth of the USDA303 strain over the USDA103 strain of catfish while feed efficiency was similar. Using flow-through aquaria, Li et al. (2006) found small improvements in final weight (5.1%) and feed efficiency (3.3%) for the USDA303 strain compared to the USDA103 strain. In another flow-through aquaria study, Peterson et al. (2008b) found no significant improvement in weight gain or feed efficiency comparing these two genetic groups. The inconsistencies reported for growth and FCR among the above-mentioned studies might be the result of a difference in environment, density of the fish (initial weight of fish and length of study), or feeding regimes.

Whole body composition indices for the four genetic groups were similar whether final weight was added as covariate or left out of the model. In a study comparing hybrid and blue catfish to USDA103 and USDA303 catfish, Small (2006) found a tendency toward lower protein and higher fat content for USDA103 and USDA303 catfish. In a study comparing USDA102 (Red River strain) catfish, Peterson et al. (2008b) also found a tendency toward lower protein and higher fat content for both USDA103 and USDA303 catfish. However, in both of these studies, when final weight was used as a covariate in the statistical analysis, body composition indices were not significantly different among genetic groups.

There was no significant difference among the four lines in converting dietary protein to body protein as reflected in similar NR. However, the fast growing, USDA403, and USDA103 strains had higher PER compared to industry pool. This would suggest that the industry pool fish were not as efficient as the other three strains in converting feed and dietary protein to weight gain. Other researchers have also found NR

and PER to be similar between USDA103 and USDA303 catfish (Small, 2006; Peterson et al. 2008b).

The plasma cortisol levels we observed following a 10-min acute stressor were similar to those reported for stressed catfish (Davis et al. 1984; Peterson et al. 2008a). However, we found no differences in cortisol levels among the genetic groups tested. Similarly, Bosworth et al. (2004b) reported that cortisol levels were similar among USDA103, USDA102 (fish selected for improved growth and disease resistance that originated from fish collected from the Red River, North Dakota, USA), and Norris strains of catfish that had been subjected to a low water stressor for 1 h. The lack of difference in levels of cortisol post-stress may suggest. . . (I am up for suggestions).

A goal of our selective breeding program is to identify and develop lines of catfish that will represent an improvement over strains now used by catfish producers. Results of the current study demonstrate the superiority in growth of the USDA103 line of catfish (fast growing, USDA103, and USDA403) compared to a line of fish that was collected from catfish farms across the Mississippi Delta (industry pool). Continued selection of the USDA103 line will be justified only after production traits such as disease resistance, reproductive performance, and fillet yield are evaluated.

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