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Differences in Growth and Nutrient Efficiency Between and Within Two Channel Catfish *Ictalurus punctatus* Strains

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Abstract

A 6-wk growth study was conducted comparing fingerling (mean weight = 24.7 g) USDA103 strain channel catfish *Ictalurus punctatus* to Norris strain channel catfish in an effort to determine strain differences in growth and nutrient efficiency. Variability within strains also was assessed by randomly selecting four families from each strain for comparison. On average, USDA103 fish gained significantly ($P < 0.05$) more weight (51.2 vs. 31.7 g) and length (4.7 vs. 4.1 cm) compared to Norris strain catfish. Significantly ($P < 0.05$) greater feed consumption (56.6 vs 41.3 g) and feed efficiency (95.7 vs. 89.9) for USDA103 catfish were also observed. Family differences in weight and length gain and feed intake were significant ($P < 0.05$) among USDA103 families; whereas, only differences in feed intake and feed efficiency were significant ($P < 0.05$) among Norris families. Nitrogen retention was higher ($P < 0.05$) for the Norris strain catfish (35.6%) relative to the USDA103 strain average (31.0%). The results of this study reiterate the superior growth and feed efficiency of the USDA103 strain of channel catfish. Observed differences among USDA103 families suggest that further improvements in weight gain can be made through selective breeding; however, improvements in feed and protein efficiency may be difficult.

Improving channel catfish *Ictalurus punctatus* growth and feed efficiency are two important goals of a selective breeding program. An improved strain of channel catfish, NWAC103, was developed and evaluated at the USDA-ARS Catfish Genetics Research Unit under the experimental name USDA103 and jointly released to commercial producers in cooperation with the Mississippi Agricultural and Forestry Experiment Station, Thad Cochran National Warmwater Aquaculture Center, Stoneville, Mississippi, USA. Results of experimental trials have demonstrated that both the commercial (NWAC103) and experimental (USDA103) lines of catfish have excellent growth compared to other strains of catfish currently being used by commercial producers (Li et al. 1998, 2001; Silverstein et al. 1999, 2000; Jackson et al. 2003; Peterson et al. 2004). Comparison of the USDA103 line of catfish with Norris strain catfish, originating from the Norris fish farm in Arkansas (Dunham and Smitherman 1984) has consistently shown improvements in weight gain and feed consumption for USDA103 catfish, with feed efficiency also shown to be improved in some studies (Silverstein et al. 1999; Wolters et al. 2000).

To date, no studies have evaluated nitrogen and energy efficiency of the USDA103 strain catfish. Since USDA103 catfish appear to consume more feed than catfish of other common strains, a comparison of nutrient efficiency with a commercially produced strain is warranted. The purposes of this study were to verify genetic differences between Norris and USDA103 catfish strains for growth rate and feed efficiency, determine whether differences exist for nitrogen and energy retention between these two strains, and determine if differences in growth and efficiency indices could be detected among families within the two strains.

Methods and Materials

Animals

USDA103 strain channel catfish were compared to Norris strain channel catfish. Variability within strains was assessed by selecting four families from each strain for comparison. Families of similar average weight were randomly selected from both strains with no constraint on age. All fish used in the study were from natural pond

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spawns and reared in indoor tanks in a common environment (water temperature 26 C, pH 8.6, and dissolved oxygen > 5.0 mg/L) under common management and feeding conditions at the USDA-ARS Catfish Genetics Research Unit, Stoneville, Mississippi, USA.

Experimental Design

The study was conducted in a double-blind format, and in accordance with the principles and procedures approved by the Institutional Animal Care and Use Committee, USDA-ARS Catfish Genetics Research Unit. Two weeks prior to starting the experiment, channel catfish fingerlings (mean weight ± SEM; 24.7 ± 0.5 g) from four Norris and four USDA103 families were stocked into 32 23-L aquaria. Each aquarium was stocked with 14 full-sib fingerlings, and each family was replicated in four aquaria. During the 2-wk acclimation period all fish were fed a 36% protein floating catfish feed (Farmland Industries, Inc., Kansas City, Missouri, USA) once daily to apparent satiation. Apparent satiation was achieved by offering small quantities of feed to the fish by hand until feeding activity stopped. During the growth trial, feeding was increased to twice daily to apparent satiation, and weight of feed consumed was recorded daily.

At the start of the growth study, seven fish from each aquarium were removed and euthanized by overdose in a solution of 300-ppm tricaine methanesulphonate (TMS; Argent Chemical Laboratories, Redmond, Washington, USA), and carcasses were stored at -20 C for subsequent proximate analyses and energy determination. The remaining seven fish in each aquarium were anesthetized in a solution of 100 ppm TMS, weighed, and lengths measured. The growth trial was terminated at 6-wk, and the remaining seven fish per aquarium were euthanized, weighed, measured, and then stored at -20 C for subsequent proximate analyses and energy determination. Weight gain (mean weight at 6-wk – mean initial weight), length gain (mean length at 6-wk – mean initial length), and feed efficiency (FE = 100 X weight gain / feed consumed) were calculated. Proximate analyses and energy determination were conducted in duplicate on individual carcass and diet samples. Crude protein (combustion method), crude fat (ether extract), moisture (oven drying), and gross

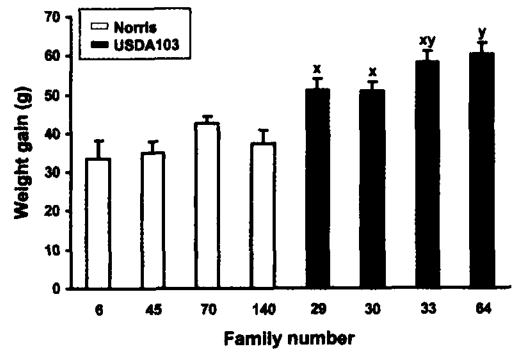

FIGURE 1. *Weight gain of channel catfish fed to satiety for 6 wk. Strain means for Norris (37.1 g) and USDA103 (54.2 g) were significantly different* ($P < 0.05$)*. Family means were not significantly different within the Norris strain* ($P > 0.05$)*. Significant differences* ($P < 0.05$) *among families within the USDA103 strain are indicated by different letters.*

energy (bomb calorimetry) content of homogenized diet and carcasses were determined using methods described by the AOAC (1995). Protein efficiency ratio (PER = weight gain / crude protein consumed), apparent nitrogen retention (100 X nitrogen consumed / nitrogen gained), and apparent energy retention (100 X gross energy consumed / gross energy gained) were calculated.

All data were subjected to analysis of variance and a least significant difference procedure (Steel and Torrie 1980) using Statistical Analysis System version 9.0 software (SAS Institute, Inc., Cary, North Carolina, USA). Each aquarium was used as the experimental unit, and variation among aquaria within strain was used as the experimental error in tests of significance. A level of $P < 0.05$ was used to determine significance, with $P < 0.1$ suggesting a tendency toward significance.

Results

Overall body weight and length gain were significantly ($P<0.05$) different between the two strains of catfish (Figs. 1, 2). USDA103 catfish gained 54.2 g over the 6-wk study compared to 37.1 g for Norris catfish. Within strain differences for weight and length gain did not exist ($P > 0.05$) among Norris catfish families, but did exist ($P < 0.05$) among families of the USDA103 catfish. Additionally, differences in type of gain were apparent among the USDA103 catfish families.

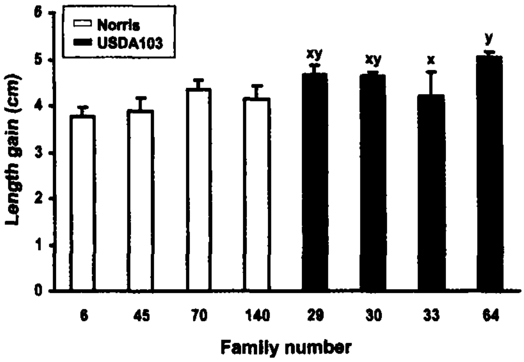

FIGURE 2. *Length gain of channel catfish fed to satiety for 6 wk. Strain means for Norris (4.1 cm) and USDA103 (4.7 cm) were significantly different* ($P < 0.05$). *Family means were not significantly different within the Norris strain* ($P > 0.05$). *Significant differences* ($P < 0.05$) *among families within the USDA103 strain are indicated by different letters.*

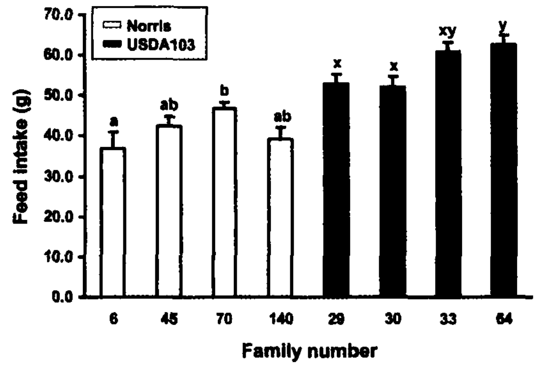

FIGURE 3. *Feed intake of channel catfish fed to satiety for 6 wk. Strain means for Norris (41.3 g) and USDA103 (56.6 g) were significantly different* ($P < 0.05$). *Significant differences* ($P < 0.05$) *among families within strains are indicated by different letters.*

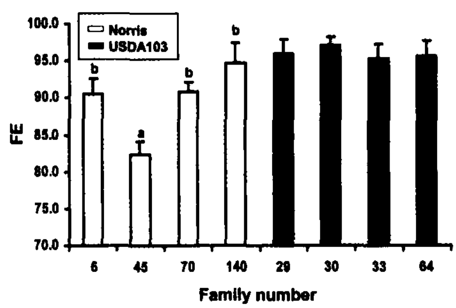

FIGURE 4. *Feed efficiency (FE) of channel catfish fed to satiety for 6 wk. Strain means for Norris (89.8) and USDA103 (95.7) were significantly different* ($P < 0.05$). *Significant differences* ($P < 0.05$) *among families within the Norris strain are indicated by different letters. Family means were not significantly different within the USDA103 strain* ($P > 0.05$).

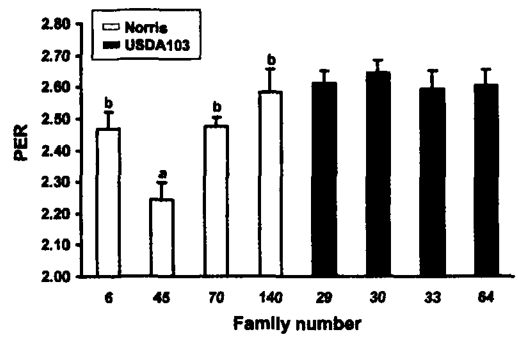

FIGURE 5. *Protein efficiency ratio (PER) of channel catfish fed to satiety for 6 wk. Strain means for Norris (2.44) and USDA103 (2.61) were significantly different* ($P < 0.05$). *Significant differences* ($P < 0.05$) *among families within the Norris strain are indicated by different letters. Family means were not significantly different within the USDA103 strain* ($P > 0.05$).

Family 33 had similar ($P > 0.05$) weight gain to family 64, but reduced ($P < 0.05$) length gain.

Feed intake was also significantly ($P < 0.05$) different between catfish strains (Fig. 3). Overall, USDA103 catfish consumed 56.6 g of feed per fish over the 6-wk study compared to 41.3 g of feed per Norris catfish. Differences within strain were also significant ($P < 0.05$) for both USDA103 and Norris catfish families. Weight gain and feed intake were highly correlated among USDA103 catfish families ($P = 0.002$; $r^2 = 0.997$), but not among Norris catfish families ($P < 0.154$; $r^2 = 0.715$).

Overall feed efficiency and protein efficiency were also significantly ($P < 0.05$) different between strains (Figs. 4, 5). USDA103 catfish were 95.7% efficient in the conversion of consumed feed to body weight gain and had an average strain PER of 2.61. Norris catfish had an average FE of 89.9% and an average PER of 2.44. No differences ($P > 0.05$) for either FE or PER were observed among USDA103 catfish families; however, significant ($P<0.05$) differences were observed among Norris catfish families for both FE and PER.

Analyzed dietary gross energy and nitrogen

TABLE 1. *Mean (± SEM) nitrogen and energy balance indices for families from two channel catfish strains fed to satiety for 6 wk (N = 4). Means within columns with different letters are significantly different within strain* (P < *0.05). USDAA103 strain means followed by an asterisk (*) are significantly different from Norris strain means* (P < *0.05). Two asterisks (**) indicate a tendency toward differences between strain means* (P < *0.1).*

Strain	Family number	Nitrogen intake (g)	Nitrogen gain (g)	Nitrogen retention (%)	Energy intake (kcal)	Energy gain (kcal)	Energy retention (%)
Norris	6	2.16 ± 0.25a	0.73 ± 0.14a	33.88 ± 4.2	159.6 ± 18.6 a	78.0 ± 10.8ab	41.8 ± 2.7a
	45	2.49 ± 0.16ab	0.80 ± 0.03ab	32.3 ± 1.1	183.8 ± 11.3ab	76.8 ± 4.4b	49.0 ± 2.2ab
	70	2.75 ± 0.08b	1.07 ± 0.03b	38.9 ± 1.1	203.1 ± 6.2b	99.6 ± 6.1b	48.9 ± 2.5ab
	140	2.30 ± 0.17ab	0.87 ± 0.14ab	37.5 ± 4.6	169.9 ± 13.0ab	87.2 ± 6.2ab	51.3 ± 2.5b
Strain mean		2.43 ± 0.10	0.87 ± 0.06	35.6 ± 1.6	179.1 ± 7.2	85.4 ± 4.0	47.7 ± 1.4
USDA103	29	3.12 ± 0.14x	0.92 ± 0.15	29.0 ± 3.3	230.2 ± 10.2x	103.4 ± 7.0	44.9 ± 2.7
	30	3.07 ± 0.16x	1.03 ± 0.08	33.8 ± 2.6	226.4 ± 11.8x	104.3 ± 6.2	46.1 ± 0.1
	33	3.59 ± 0.14xy	1.26 ± 0.17	34.9 ± 3.5	264.7 ± 10.0xy	123.1 ± 14.2	46.5 ±4.0
	64	3.69 ± 0.13y	0.97 ± 0.10	26.2 ± 2.0	272.2 ± 9.9y	128.3 ± 10.1	47.1 ± 3.3
Strain mean		3.36 + 0.10*	1.05 ± 0.06**	31.0 ± 1.5*	248.4 + 7.0*	114.8 ± 5.0*	46. 2 ± 1.3

content were 4.3 kcal/g and 5.9%, respectively. Indices of nitrogen and energy balance are presented in Table 1. Differences ($P < 0.05$) in nitrogen and energy intake between and within strains corresponded to observed differences in feed intake. The amount of nitrogen gained tended to be higher ($P < 0.10$) for USDA103 catfish compared to Norris catfish, and energy gain was significantly higher ($P < 0.05$) for the USDA103 strain. No strain differences ($P > 0.05$) were observed for apparent energy retention; however, nitrogen retention was higher ($P < 0.05$) for Norris strain catfish compared to USDA103 strain catfish. Among the USDA103 families, significant (P < 0.05) differences were observed for nitrogen and energy intake only. Indices appeared to be more variable within the Norris strain, with significant ($P < 0.05$) among-family differences being observed for nitrogen intake, nitrogen gain, energy intake, energy gain, and apparent energy retention.

Average body composition indices for the two strains indicated a tendency toward lower ($P < 0.10$) protein and moisture content and higher ($P < 0.05$) fat content for USDA103 catfish compared to Norris catfish (Table 2). Differences ($P < 0.05$) in moisture and fat content were observed among families within both strains.

Discussion

Despite a number of publications on the nutrition and growth of USDA103 (NWAC103) strain channel catfish and comparisons with other commonly cultured channel catfish strains (Li et al. 1998, 2001; Silverstein et al. 1999, 2000, 2001; Wolters et al. 2000; Jackson et al. 2003), this manuscript presents the first comparison of nitrogen and energy retention between the USDA103 and Norris strains. The study presented here also demonstrates the variability of various growth and nutritional indices within the USDA103. Such information may prove useful in both the continued selective breeding of USDA103 channel catfish and the nutritional optimization of feeds for this genetically improved strain.

The results of the present study clearly indicate that improvements in growth within the USDA103 strain are positively correlated to increased feed intake. Silverstein et al. (1999), in comparing USDA103 and Norris strains of channel catfish, observed a similar correlation and indicated genetic differences existed in growth, feed efficiency, and feed intake between the two strains. Their results demonstrated that the USDA103 strain catfish consumed significantly more feed, grew faster, and were more efficient than Norris strain catfish. In

TABLE 2. *Mean (± SEM) body composition indices (wet basis) of families from two channel catfish strains fed to satiety for 6 wk (N = 4). Means within columns with different letters are significantly different within strain (P < 0.05). USDA 103 strain means followed by an asterisk (*) are signficiantly different from Norris strain means (P < 0.05). Two asterisks (**) indicate a tendency toward differences between strain means (P < 0.1).*

Strain	Family number	Moisture (%)	Protein (%)	Fat (%)
Norris	6	73.6 ± 0.3b	14.2 ± 1.0	7.1 ± 0.2ab
	45	73.9 ± 0.1b	13.5 ± 0.6	6.6 ± 0.6a
	70	72.4 ± 0.3a	14.7 ± 0.5	7.8 ± 0.3b
	140	73.5 ± 0.3b	14.1 ± 0.6	6.8 ± 0.4ab
	Strain mean	73.4 ± 0.2	14.1 ± 0.3	7.1 ± 0.2
USDA103	29	73.4 ± 0.1x	13.3 ± 0.8	7.2 ± 0.3x
	30	73.0 ± 0.2xy	12.8 ± 0.4	7.9 ± 0.4 xy
	33	72.8 ± 0.4xy	13.8 ± 0.9	7.8 ± 0.2 xy
	64	72.3 ± 0.3y	13.3 ± 0.9	8.2 ± 0.1y
	Strain mean	72.9 ± 0.2**	13.3 ± 0.4**	7.8 ± 0.2*

an effort to determine the genetic component of feed intake for USDA103 catfish, Silverstein et al. (2001) found that the mean change in weight of family groups was significantly correlated with mean feed intake. The same was found in the present study. In fact, USDA103 strain catfish in the present study clearly demonstrated overall improvements in growth, feed efficiency and protein efficiency compared to Norris strain catfish. Although the present study was limited to only four families per strain, observed differences among USDA103 families suggests that improvements in weight gain, while correlated to feed intake, can still be made through selective breeding. On the contrary, feed and protein efficiency were not different among the four USDA103 families. As such, further improvement of efficiency traits in the USDA103 strain through selective breeding may prove difficult.

Results from the present study indicated that the USDA103 catfish have more (0.7%) average body fat compared to Norris strain catfish. Higher levels of fillet fat in USDA103 strain catfish compared to Mississippi Normal catfish (Li et al. 1998, 2001) have been attributed to increased feed intake and faster growth exhibited by the USDA103 strain. These researchers also reported lower levels of visceral fat in USDA103 catfish compared to Mississippi Normal catfish. Jackson et al. (2003) suggested that a slight increase in fat content is generally not detrimental unless dressed yield is impacted.

In addition to a higher carcass fat content, average nitrogen retention was approximately 4% lower for USDA103 catfish in the present study. Since overall feed efficiency and nitrogen gain was improved in the USDA103 strain, lower nitrogen retention was also likely a result of increased feed intake and faster growth, suggesting differences in nutrient partitioning relative to feed intake and growth rate. Li et al. (1998) evaluated the effects of feeding diets containing three concentrations of protein and digestible energy on catfish growth, feed efficiency, and fillet composition. Their results indicated that fish fed a 35% protein diet with a digestible energy/protein ratio of 8.1 kcal/g gained more weight and converted feed more efficiently than fish fed either a 25 or 45% protein diet regardless of strain. Jackson et al. (2003) compared 28 and 32% protein diets fed to NWAC103 catfish, and the only difference they found was in fillet protein level. Genotype-nutrition interactions have been reported for common carp *Cyprinus carpio* (Wohlfarth et al. 1983) and Nile tilapia *Oreochromis niloticus* (Romana-Eguia and Doyle 1992). Studies relating changes in dietary protein quantity, or more specifically amino acid quantity, or DE/P ratios on USDA103 nitrogen retention may be needed to optimize growth and nutrient efficiency in this genetically improved strain. Ultimately, research to "fine-tune" nutrient efficiency will depend upon the economics of small gains in production or product quality verses the cost of nutrients and feeds.

In summary, the USDA103 strain of channel catfish demonstrated superior growth traits (weight gain, length gain, and feed efficiency) when compared to Norris strain catfish. Small differences in whole-body proximate composition and nitrogen retention between the two strains were likely due to differences in feed consumption and final weight. Although no differences were observed for feed and protein efficiency among the USDA103 families, the observed differences in weight and length gain among the USDA103 families suggest that further improvements in growth rate can be made through selective breeding of this catfish line.

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