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Aquaculture 228 (2003) 81–90
Aquaculture
www.elsevier.com/locate/aqua-online

Dress-out and fillet yields of channel catfish, *Ictalurus punctatus*, blue catfish, *Ictalurus furcatus*, and their F_1, F_2 and backcross hybrids

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Received 16 March 2003; received in revised form 16 March 2003; accepted 20 March 2003

Abstract

The channel catfish, *Ictalurus punctatus*, ♀ × blue catfish, *Ictalurus furcatus*, ♂ F_1 hybrid showed increased processing yields over the most commonly cultured catfish, channel catfish, in the US. The F_1 hybrid had higher dress-out and fillet percentage (61.1% and 45.7%, respectively) than channel catfish (57.5%, 42.5%), blue catfish (58.9%, 44.4%), F_2 hybrid catfish (57.3%, 42.5%), F_1 × channel catfish (57.3%, 42.7%), F_1 × blue catfish (58.3%, 42.4%), blue catfish × F_1 (58.2%, 43.2%), and channel catfish × F_1 (56.8%, 42.1%). Individual heterosis had a strong positive effect on dress-out and fillet percentage. Channel catfish additive genetic effects had a strong negative effect on dress-out and fillet percentage. Females had greater dress-out (58.4% to 57.9%) and fillet percentage (43.6% to 43.0%) than males ($P < 0.05$). Utilization of channel-blue F_1 hybrids will increase processing yields and may allow farmers to demand a higher price for their product.

Keywords: Channel catfish, *Ictalurus punctatus*; Blue catfish, *Ictalurus furcatus*; Hybridization; Backcrossing; Selection; Processing yields

1. Introduction

F_1 hybrids of female channel catfish (*Ictalurus punctatus*) × male blue catfish (*Ictalurus furcatus*) show overdominance in growth (Giudice, 1966; Yant et al., 1976) and better

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0044-8486/$ - see front matter © 2003 Published by Elsevier Science B.V.
doi:10.1016/S0044-8486(03)00245-X

performance than channel catfish for low dissolved oxygen tolerance, disease resistance, uniformity in body conformation, catchability, and dress-out percentage (Tave et al., 1981; Dunham et al., 1983a,b; Ella, 1984; Smitherman and Dunham, 1985; Brummet, 1986). However, producing hybrids on a commercial scale has not been practical because of reproductive isolating mechanisms between channel catfish and blue catfish (Dunham and Smitherman, 1987).

Dress-out percentage reported in the literature ranges from 56.6% for channel catfish (Chrisman et al., 1983) and channel-blue hybrids (Ramboux, 1990) to 68.6% for channel catfish (El-Ibiary and Joyce, 1978). Part of this variation is from the techniques used to process the fish. Ammerman (1985) found that mechanical skinners produced greater dress-out percentage (65.3%) than hand skinning (58.5%) in channel catfish. Strain, sex, age, size and species may also affect dress-out percentage.

Percent dress-out increased 3% to 4% from 13- to 22-month-old channel catfish of similar average size (Dunham et al., 1985). Third summer channel and blue catfish had about 2% higher dress-out than second summer fish (Grant and Robinette, 1992). Lovell and Li (1992) found third-year fish had 5.5% higher dress-out than second-year fish. Bondari et al. (1985) graded channel catfish into large (687 g), medium (583 g), and small (440 g) sizes. They found no difference in dressing percentage between these size categories.

Interspecific hybridization and intraspecific crossbreeding may improve a farm animal by non-additive genetic effects. However, the maximum dominance advantage is present in the first generation (F_1) and will be partially lost in future generations. Also, there will be a loss of the epistatic superiority from the pure breeds due to segregation and recombination of gametes from crossbred parents. This is known as epistatic recombination loss (Dickerson, 1969, 1973). However, the new additive genetic variance introduced from hybridization may be two to three times greater than that introduced by mutation (Grant and Grant, 1994) and maybe used by fish breeders in a selection program.

Heritability for carcass traits in channel catfish were moderate to high; however, if these traits are standardized for size the heritability is decreased to zero (El-Ibiary and Joyce, 1978; Dunham, 1987). This indicates that classic selective breeding programs to increase carcass traits in channel catfish may show little improvement. Selection of the top performing higher generation hybrids may be an alternative for mixing of the genome and selection for the best traits from the original parents (Smith, 1970; Lasley, 1987). Hybrids could also be backcrossed and the top performers selected (Dalton, 1985). Selection of F_2, F_3, or backcrossed catfish hybrids for growth, catchability, reproductive ability, dress-out percentage, and other traits may provide a practical source of improved catfish for commercial fish farmers. The present research examined the dress-out and fillet percentage of channel catfish, blue catfish, channel catfish × blue catfish F_1 and F_2 hybrids and the F_1 hybrid backcrosses grown in earthen ponds.

2. Materials and methods

Catfish were artificially produced in the spring of 1993 using the methods of Argue (1996). The following catfish crosses were produced (♀ × ♂) (strains are in parenthesis) from strains currently available at Auburn University: channel × channel (Stoneville, MS) (eight pairs), blue × blue (Tombigbee (T) × Auburn, blue mix) (four pairs), channel × blue (F_1) (Kansas × RioGrande, Marion × RioGrande) (five pairs), F_1, × F_1 (F_2) (F_2, mix) (six pairs), F_1 × channel (F_1 mix × Auburn) (two pairs), channel × F_1 (Marion × F_1 mix, Mississippi × F_1 mix, channel mix × F_1 mix) (three pairs) F_1 × blue (F_1 mix × Craft, F_1 mix × blue mix (two pairs) and blue × F_1 (T × F_1 mix (two pairs).

Fry were stocked (22,250 fry/ha) into fourteen 0.04 ha ponds (one or two ponds per group) 1 to 2 weeks after hatch. After harvesting and heat branding in October 1993, the fingerlings were divided among three 0.04-ha communal ponds at 16,300 fingerlings/ha. The fish were 20–40 g when heat branded. Fish were fed ad libitum and harvested in October 1994 at 16 months of age.

A random sample from each cross was slaughtered to evaluate dress-out and fillet percentage. Dress-out percentage was the weight of the fish without head, viscera, and skin, divided by total weight. Fillet percentage was the weight of muscle (removed with an electric knife from the vertebra of the dressed fish) divided by total weight.

Data was analyzed using ANOVA, and if an effect was significant ($P<0.05$), *t*-tests were conducted to find differences among the means.

Carcass yields were evaluated with the following model:

$$Y_{ijm} = \mu + C_i + S_j + (CS)_{ij} + e_{ijm}$$

where μ = the population mean; C = cross; S = sex; e = error; $i=1,2,\ldots, 8$; $j=1,2$; $m=1,2,\ldots, n$ where n is the number of fish in each cross.

The following multiple regression model was used to partition the various genetic effects, and followed that of Dickerson (1969) and Tave et al. (1989, 1990)

$$E_j = b_0 + b_1\text{Ach} + b_2\text{ABl} + b_3\text{HI} + b_4\text{HM} + b_5\text{RI} + D_j$$

where E_j = least square means of the *j*th group; b_0 = least-square means; b_1 and b_2 = partial regression coefficients of the dependent variable on species additive genetic effects for channel and blue catfish, respectively; Ach and ABl = species additive genetic effects; b_3 = partial regression coefficient of the dependent variable on individual heterosis; HI = individual heterosis (dominance effects); b_4 = partial regression coefficient of the dependent variable on maternal heterosis; HM = maternal heterosis; b_5 = partial regression coefficient of the dependent variable on the loss of heterotic superiority due to individual epistatic recombination in F_1 + crosses; RI = individual epistatic recombination loss; D_j = deviation of the means from the model.

The model results in a singular matrix (Table 1), because the sum of the additive genetic effects is equal to one. Additive genetic effects were computed as deviations from blue catfish to remove this dependency. After these restrictions were imposed on the matrix, the multiple regression model became:

$$E_j = b_0 + b_{\text{A}}\text{Ach} + b_{\text{HI}}\text{HI} + b_{\text{HM}}\text{HM} + b_{\text{RI}}\text{RI} + D_j$$

where b_0 = least square means for blue catfish; b_{A} = partial regression coefficient for channel catfish additive genetic effects; Ach = channel catfish additive genetic effects; b_{HI} = partial regression coefficient for individual heterosis; b_{HM} = partial regression coef-

Table 1
Coefficients of additive genetic effects, individual heterosis (dominance effects), maternal heterosis, and individual epistatic recombination loss for channel catfish (Ch) (*I. punctatus*) and blue catfish (Bl) (*I. furcatus*) and their channel ♀ × blue ♂ F_1, F_2 and backcross hybrids

Cross (♀ × ♂)	Additive Effects		Individual heterosis	Maternal heterosis	Epistatic recombination loss
	Ch	Bl			
Ch × Ch	1.0	0.0	0.0	0.0	0.0
Bl × Bl	0.0	1.0	0.0	0.0	0.0
Ch × Bl (F_1)	0.5	0.5	1.0	0.0	0.0
F_1 × F_1 (F_2)	0.5	0.5	0.5	1.0	0.5
Ch × F_1	0.75	0.25	0.5	0.0	0.25
F_1 × Ch	0.75	0.25	0.5	1.0	0.25
Bl × F_1	0.25	0.75	0.5	0.0	0.25
F_1 × Bl	0.25	0.75	0.5	1.0	0.25

ficient for maternal heterosis; b_{RI} = partial regression coefficient for individual epistatic recombination loss.

3. Results

The channel × blue F_1 hybrid had the highest dress-out and fillet percentages (Table 2). Dress-out percentage increased with increasing amounts of blue catfish ancestry (Fig. 1). The relationships between dress-out percentage and percent blue catfish genes, and between fillet percentage and percent blue catfish genes were more quadratic than linear. There is significant linear component for dress-out percentage, $r^2 = 0.72$, $P = 0.016$, but the quadratic component accounts for a greater portion of the variation, $r^2 = 0.92$, $P = 0.007$. For fillet percentage the linear component was not significant, $r^2 = 0.28$, but the quadratic component was significant, $r^2 = 0.83$, $P = 0.029$. Channel catfish additive genetic effects and individual epistatic recombination loss (Table 3) decreased dress-out and fillet percentage as expected from Fig. 1 and Table 2. Individual heterosis positively affected

Table 2
Dress-out and fillet percentage of channel catfish (Ch) *I. punctatus*, blue catfish (Bl) *I. furcatus* and their channel ♀ × blue catfish ♂ F_1, F_2 and backcross hybrids harvested at 16 months

Cross (♀ × ♂)	%Blue	*N*	Ave. wt. (g)	Dress-out percentage				Fillet percentage			
				Mean	Range	S.D.	C.V.	Mean	Range	S.D.	C.V.
Ch × Bl	50	124	831	61.1a	55.0–64.7	1.5	2.4	45.7a	36.6–49.5	2.0	4.3
Bl × Bl	100	30	365	58.9b	55.3–64.7	1.9	3.3	44.4b	40.0–48.6	2.0	4.5
F_1 × Bl	75	33	414	58.3bc	53.4–68.1	2.7	4.7	42.4cd	30.5–52.8	4.1	9.7
Bl × F_1	75	118	429	58.2bc	50.6–62.9	2.0	3.4	43.2c	33.6–47.8	2.5	5.8
Ch × Ch	0	68	556	57.5cd	53.6–79.7	3.2	5.5	43.1c	35.1–58.5	3.0	6.9
F_1 × F_1	50	26	389	57.3cde	48.9–61.9	2.6	4.6	42.5cd	35.1–46.6	2.8	6.7
F_1 × Ch	25	108	378	57.3de	48.6–67.6	2.4	4.2	42.7cd	34.5–52.4	2.9	6.8
Ch × F_1	25	194	334	56.9e	44.7–64.7	2.3	4.1	42.1d	32.5–50.4	2.5	5.9

Values in the same column sharing the same letter are not significantly different (P>0.05).

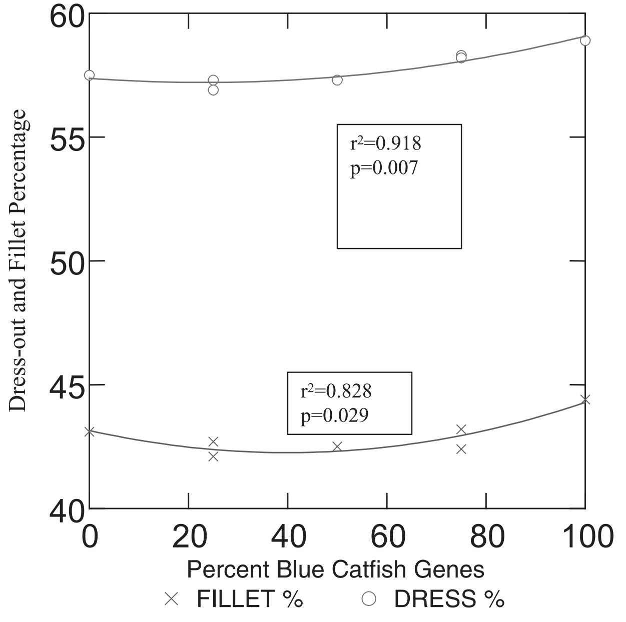

Fig. 1. Expected percent blue catfish *I. furcatus* genes and dress-out and fillet percentage (without data from the channel catfish (*I. punctatus*) ♀ × blue catfish ♂ F_1 hybrids due to overdominance in the F_1 hybrid). There is significant linear component for dress-out %, $r^2 = 0.72$, $P = 0.016$, but the quadratic component accounts for a greater portion of the variation, $r^2 = 0.92$, $P = 0.007$. For fillet percentage, the linear component was not significant, $r^2 = 0.28$, but the quadratic component was significant, $r^2 = 0.83$, $P = 0.029$.

dress-out and fillet percentage as demonstrated by the overdominance of the F_1 hybrid. Blue catfish had higher dress-out and fillet percentages than channel catfish (Table 2).

The F_1 hybrid and blue catfish were more uniform in dress-out and fillet percentage as indicated by both their standard deviation (SD) and coefficient of variation (CV) for both traits. There was more variation present in fillet percentage than dress-out percentage within all the crosses (Table 2).

Table 3
Multiple regression model coefficient for least square mean ± S.E. of blue catfish *I. furcatus* (b_0), and partial regression coefficients ± S.E. of channel catfish *I. punctatus* additive genetic effects (b_A), individual heterosis (b_{HI}), maternal heterosis (b_{HM}), and individual epistatic recombination loss (b_{RI}) for dress-out and fillet percentage

Coefficient	Dress-out percentage	Fillet percentage
b_0	59.8 ± 0.04**	44.35 ± 0.05**
b_a	− 2.03 ± 0.05**	− 1.47 ± 0.06**
b_{HI}	2.81 ± 0.04**	1.95 ± 0.05**
b_{HM}	0.41 ± 0.03**	0.35 ± 0.04**
b_{RI}	− 7.80 ± 0.10**	− 7.49 ± 0.12**
r^2	0.956**	0.911**

Asterisk on the coefficients indicate significant differences from zero.

** $P < 0.01$.

Table 4
Dress-out and fillet percentage of strains within genetic crosses of channel catfish (*I. punctatus*) and blue catfish (*I. furcatus*)

Genetic cross strain	*N*	Mean wt. (g)	Dress-out percentage	Fillet percentage
Channel × blue (F_1)				
Kansas × RioGrande	50	827	61.5a	45.9a
Marion × RioGrande	74	835	60.8a	45.6a
Blue × blue				
Tombigbee × Auburn	6	342	58.0a	44.5a
Blue × mix	24	371	59.2a	44.4a
F_1 × blue				
F_1 mix × Craft	11	388	58.7a	42.6a
F_1 mix × blue mix	22	426	58.1a	42.3a
Channel × channel				
Stoneville	25	559	57.5a	43.3a
Mississippi	43	554	57.6a	43.0a
Channel × F_1				
Marion × F_1 mix	82	384	56.7a	42.2a
Mississippi × F_1 mix	52	290	57.3b	42.0a
Channel mix × F_1 mix	60	305	56.7a	42.2a

Different letters within a cross indicate significant differences between strains within that genetic group ($P < 0.05$).

All r^2 of body weight by fillet or dress-out percentage within crosses were ≤ 0.1 except the channel catfish and F_2 hybrid crosses which were less than 0.2. The r^2 for all the crosses combined was 0.18 and 0.20 for fillet and dress-out percentage, respectively. Consequently, dress-out and fillet percentages were not adjusted for weight.

Various strains were used to produce the various genotypes and backcrosses. There was no difference among genotypes within cross produced by different strains except for percent dress-out within the channel × F_1 backcross (Table 4). There was no difference in fillet percentage among genotypes within each cross. Except for the one significant difference for the channel × F_1 backcrosses, strain of parent had no significant effect on performance.

Table 5
Dress-out and fillet percentage of channel catfish (*I. punctatus*), blue catfish (*I. furcatus*), and their F_1, F_2 and backcrossed hybrids by sex

Cross	Dress-out percent		Fillet percent	
	♀	♂	♀	♂
Channel × blue (F_1)	61.6*	60.7	46.5*	45.2
Blue × blue	59.8	58.7	44.9	44.4
Blue × F_1	58.4	58.0	43.5	43.1
Channel × channel	57.8*	56.9	43.5	42.5
F_1 × channel	57.7*	57.0	43.0	42.5
F_1 × F_1 (F_2)	58.1	57.1	43.0	42.5
Channel × F_1	57.0	56.8	42.3	42.0
F_1 × blue	58.2	58.0	42.3	42.5

* Indicates significant difference between male and female within a cross (*t*-test; $P < 0.05$).

Sex and cross had significant effects on fillet and dress-out percentage in this study. There was no interaction between sex and cross (P>0.3). Overall, females had higher (P < 0.05) fillet (43.6% to 43.0%) and dress-out percentage (58.4% to 57.9%) than males. Within each cross (except fillet percentage in the $F_1 \times$ blue), the female had higher observed dress-out and fillet percentage than the male (Table 5). However, only the F_1 hybrid female had statistically higher fillet percentage than their male. The female F_1 hybrid, channel catfish, and $F_1 \times$ channel catfish had statistically greater dress-out percentage than their males.

4. Discussion

In the current study, blue catfish had higher dress-out percentage than channel catfish. Previous research has also shown higher dress-out percentage for blue catfish than channel catfish (Chappell, 1979; Tidwell and Mims, 1990; Grant and Robinette, 1992). However, Grant and Robinette (1992) found no difference in fillet percentage between blue catfish and channel catfish and no difference in percent dress-out of channel catfish and blue catfish in the third summer of growth.

Dunham et al. (1985) found a correlation between dress-out percentage and body weight in 13-month channel catfish (r = 0.3) but not in 22-month channel catfish (r = − 0.07). Third-year channel catfish (1579 g) had higher dress-out percentage than second-year channel catfish (462 g) (66.3% to 60.8%) (Lovell and Li, 1992). Ramboux (1990) found a size effect on dress-out in fall harvested F_1 hybrids but not in spring harvested F_1 hybrids. Ramboux (1990) found that dressing percent was positively related to increasing body weight. In the current study, the relationship was weak between body weight and fillet or dress-out percentage within each cross. All r^2 within crosses were ≤ 0.1 except the channel catfish and F_2 hybrid crosses which were less than 0.2. The r^2 for all the crosses combined was 0.18 and 0.20 for fillet and dress-out percentage, respectively. The relationship between body weight and carcass yield appears weak at best, and is complicated by age, size, genotype and season.

There has been large variation in dress-out percentage among strains of channel catfish reported in the literature (Dunham et al., 1983a). The Kansas strain of channel catfish had 59.3% dress-out while the Rio Grande strain had 64.0% (Dunham et al., 1983a). A few channel catfish strains had dress-out percentages as high as the blue catfish, and dress-out percentage was higher in blue catfish than F_1 hybrids (blue 64.3, F_1 62.0, and channel 61.2%). Blue catfish have higher dress-out than most strains of channel catfish (Dunham et al., 1993). Dunham et al. (1983a) found blue catfish had the highest observed dressing percentage but the Auburn and Rio Grande strains of channel catfish were not significantly different than blue catfish. Grant and Robinette (1992) observed blue catfish dress-out from 60.3% to 63.2% and channel catfish dress-out from 58.8% to 62.3% up to the second winter. Yant (1975) found F_1 hybrid dress-out of 64.5% and channel catfish dress-out of 61.2%. Apparently, the strain of parent can affect whether or not the hybrid exhibits heterosis for dress-out percentage (Smitherman et al., 1983). However, in this study, there was no difference among genotypes produced by different parent strains within each cross except for percent dress-out within the channel × F_1 backcross (Table 4). There was no difference in fillet percentage among genotypes produced by different parent strains within each cross.

Male channel catfish generally have larger heads than females (El-Ibiary et al., 1976). However, the females may have more visceral fat (Dunham et al., 1985). Male channel catfish had 1% to 2.5% higher dress-out in one study (Bondari et al., 1985). However, other researchers reported little to no effect of gender on dress-out percentage (El-Ibiary et al., 1976; El-Ibiary and Joyce, 1978; Bondari, 1980; Dunham et al., 1985; Ramboux and Dunham, 1991). Sex and cross had significant effects on fillet and dress-out percentage in this study. There was no interaction between sex and cross (P>0.3). Overall, females had higher ($P<0.05$) fillet (43.6% to 43.0%) and dress-out percentage (58.4% to 57.9%) than males. Within every cross (except fillet percentage in the F_1 × blue), the female had higher observed dress-out and fillet percentage than the male (Table 5). However, only the F_1 hybrid female had statistically higher fillet percentage than their male. The female F_1 hybrid, channel catfish, and F_1 × channel catfish had statistically greater dress-out percentage than their males. Ramboux (1990) found equal dress-out and fillet percentages between male and female F_1 hybrids. The differences among studies may be due to strain, season, size and processing techniques.

Blue catfish genes have a positive additive genetic effect on carcass traits. Backcrossing, with selection, has the potential to improve processing yields and backcrosses may spawn naturally which would give the commercial industry large amounts of seed for production. The backcrosses may be able to spawn naturally since they are expected to have 75% blue catfish or 75% channel catfish genes. The blue catfish backcrosses had more desirable carcass characteristics than the channel catfish backcrosses. There was a large amount of variation within the crosses that may allow for selection of desired traits. The channel × F_1 backcross had the lowest observed ranking among the backcrosses for dress-out and fillet percentage. Some individuals in the backcrosses (even in the channel catfish backcrosses) had higher dress-out values than the best F_1 hybrid or parent individuals. Backcrossing, with selection, has the potential to increase mean dress-out and fillet percentage above current levels. Another option might be to integrate the use of quantitative trait loci (QTL) in a selection program for dressing percentage since the heritability is low for this trait, and marker assisted selection theoretically can increase selection response for such traits (Poompuang and Hallerman, 1997). Liu et al. (in press) have generated an AFLP map and microsatellite for channel and blue catfish that can be used for QTL analysis and future marker assisted selection. Another alternative would be to utilize family selection.

Unfortunately, we have recent unpublished data indicating that the reproduction of interspecific catfish backcrosses can be severely retarded. However, we were able to produce commercial quantities of channel × F_1 backcrossed with artificial ovulation and fertilization. If future generation backcrosses show better reproductive characteristics, the feasibility of this approach will be enhanced.

An alternative approach to enhancing carcass yield would be the application of the channel × blue F_1 hybrid. The channel × blue F_1 hybrid had the highest dress-out and fillet percentage giving a 2.6% greater fillet yield than channel catfish. Individual heterosis had positive effects on dress-out and fillet percentage, although part of this increase may be due to increased percentage of the belly flap (Dunham, unpublished data). However, this is a marketable product and adds to the processor profit. Recent advances (Lambert et al., 1999; Dunham et al., 2000) in the artificial spawning technology to mass-produce the channel-blue F_1 hybrid should allow commercial application of this hybrid.

Acknowledgements

We thank Carel Ligeon, Wade Scardino, Bondu Argue, Tim Jeppsen, Nagaraj Chatakondi, and Joseph Padi for their assistance in dressing fish, and Dr. Mark West and Dr. Daryl Kuhlers for their assistance in statistical analysis. This research was supported by U.S. Fish and Wildlife Service Grant No. 14-16-0009-1550, the Alabama Catfish Producers, and Gold Kist Aquaculture Research Center. This is an Alabama Experimental Station Journal Series No. 8-975871.

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