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Survival, body weights, feed efficiency, and carcass traits of 3/4 white composite and 1/4 Duroc, 1/4 Meishan, 1/4 Fengjing, or 1/4 Minzhu pigs

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Survival, Body Weights, Feed Efficiency, and Carcass Traits of $\frac{3}{4}$ White Composite and $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu Pigs^{1,2}

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ABSTRACT: Pigs were the progeny of White Composite (WC) boars mated to F₁ Duroc × WC, Meishan × WC, Fengjing × WC, and Minzhu × WC gilts. Meishan and Fengjing crosses had more ($P < .05$) nipples than Duroc and Minzhu crosses. Meishan and Minzhu crosses had a higher survival at birth ($P < .05$) than Duroc and Fengjing crosses, but breed types did not differ significantly ($P \approx .29$) for survival to 14 or 28 d of age. Duroc crosses were heavier ($P < .05$) than Fengjing and Minzhu crosses at 0, 28, 56, 70, 98, 126, and 154 d of age; they were heavier ($P < .05$) than Meishan crosses at 0, 28, 98, 126, and 154 d of age. Chinese crosses had similar weights at most ages, although Meishan crosses were heavier ($P < .05$) than Fengjing and Minzhu crosses at 126 and 154 d of age. Breed types did not differ significantly ($P \approx .27$) for feed efficiency during the nursery period. Over the entire finishing period, Duroc-cross gilts (.3310) were less efficient ($P < .05$) than Meishan (.3436),

Fengjing (.3454), or Minzhu crosses (.3466); among barrows Meishan crosses (.3176) were least efficient ($P < .05$), Fengjing crosses (.3263) were most efficient ($P < .05$), and Duroc (.3211) and Minzhu (.3209) were intermediate but not significantly different from the Meishan or Fengjing crosses. At a constant age, Duroc crosses had longer carcasses, greater longissimus muscle area, and heavier slaughter weight, carcass weight, and weight of untrimmed cuts and trimmed cuts than the Chinese crosses ($P < .05$). There were few significant differences among breed types for carcass traits at a constant carcass weight. Results show that, relative to one-half Duroc females, incorporation of one-half Chinese females into a crossbreeding program will result in progeny with a significant decrease in rate of growth (approximately 9% for weight at 154 d of age) and a small, nonsignificant decrease in yield of trimmed lean cuts (approximately 5%) at a constant carcass weight.

Key Words: Meishan, Fengjing, Minzhu, Growth, Carcass

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Introduction

The Meishan, Fengjing, and Minzhu breeds were imported into the United States in 1989 (Rothschild et al., 1990) because they are among the most highly prolific breeds in the People's Republic of China (Li and Enfield, 1989). Research in Europe has documented the increased reproduction, decreased growth rate, and decreased lean yield of crosses involving Meishan relative to domestic European crosses (Legault and Caritez, 1983; Legault et al.,

1985; Bidanel et al., 1989, 1990, 1993; Haley and Lee, 1990; Haley et al., 1990, 1992). The future impact of these Chinese breeds on the swine industry will depend on the economic contributions of productive traits relative to reproductive traits as these breeds are used in a crossbreeding system. In order to take advantage of the genetic potential for reproduction, these Chinese breeds will contribute to the female side of a crossbreeding program. Thus, evaluation of growth and carcass traits of pigs produced by females containing various levels of Chinese germplasm will be required.

Previous reports from this location have presented data on growth (Young, 1992a), carcass traits (Young, 1992b), and reproduction (Young, 1995) of pigs produced by mating Duroc, Meishan, Fengjing, and Minzhu boars to White Composite females. This paper presents the preweaning and postweaning performance and carcass traits of pigs produced from the F₁ females.

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²Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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Experimental Procedures

The pigs in this study were either $\frac{1}{4}$ Duroc, $\frac{1}{4}$ Meishan, $\frac{1}{4}$ Fengjing, or $\frac{1}{4}$ Minzhu and the remainder $\frac{3}{4}$ White Composite. All pigs were born during two farrowing seasons (beginning approximately April 1 and October 1) and were the progeny of White Composite boars mated to F_1 crossbred gilts. The F_1 crossbred gilts were produced by mating eight Duroc, nine Meishan, eight Fengjing, and seven Minzhu boars to White Composite females. Reproduction of the F_1 dams has been reported by Young (1995). The White Composite boars and females were from advanced generations of an *inter se*-mated, composite population derived from a crossbred foundation with equal genetic contribution from Chester White, Landrace, Large White, and Yorkshire.

Pigs were born and raised in a totally enclosed production system. For details on facilities and diet composition see Young (1992a). Pigs were weighed within 12 h of birth. At 14 d, pigs were individually weighed and given access to creep feed, and males were castrated. Pigs were weighed and weaned at 28 d and moved by litter to a nursery facility. The number of pens in the nursery was less than the number of litters; thus, some litters were combined. Pen feed consumption was recorded in the nursery. Pigs were weighed at 56 d of age. At birth, only pigs partially or fully enclosed in amniotic membranes and found behind the sow were considered to be dead at birth. The number of nipples was recorded at birth without any evaluation of a nipple's potential to become functional.

Approximately 60 gilts and 48 barrows of each breed type were sampled each season to provide data on growth rate and feed efficiency during the finishing period. Pigs were chosen as equally as possible from all litters within a breed type. All pigs with a 56-d weight of ≤ 6.8 kg were discarded. As a result, six (1.5%) $\frac{1}{4}$ Meishan, eight (2.3%) $\frac{1}{4}$ Fengjing, six (1.8%) $\frac{1}{4}$ Minzhu, and eight (2.1%) $\frac{1}{4}$ Duroc pigs were discarded. Pigs within a litter were chosen by ranking the remaining pigs on 56-d weight; pigs were eliminated by alternating between the lightest and heaviest pigs, starting with the lightest pig, until the desired number from that litter was obtained. There were six to eight barrows per pen (12 pens per breed type) and 18 to 22 gilts per pen (six pens per breed type). Pigs were moved once a week to finishing pens at approximately 63 d of age. Body weight and feed consumption data were recorded at 28-d intervals from approximately 70 d of age until approximately 154 d of age. Ultrasonic backfat measurements (Renco Lean Meter, Minneapolis, MN) were recorded on gilts when the individuals in the pen averaged approximately 100 kg.

At 7-d intervals from 168 to 203 d of age, all barrows from one of the six pens of each breed type were slaughtered each season. Range of age within a

pen was generally less than 3 d. Final weight was recorded on the day of slaughter. Pigs were slaughtered at our abattoir in accordance with USDA guidelines. All carcasses were scalded and the skin was left on the carcass. After a 24-h chill, carcasses were weighed and the left side of the carcass was evaluated. Weight of the leaf fat was recorded. Carcass length was measured from the anterior edge of the first rib to the posterior edge of the aitchbone. Backfat was measured on the midline opposite the first rib, last rib, and last lumbar vertebrae. The side was then cut into the major wholesale cuts: ham, loin, picnic, Boston butt, and belly. The weight of each untrimmed cut was recorded.

The loin was cut at the 10th rib. The guidelines of NPPC (1991) were used to assign color and marbling scores each on a scale of 1 to 5. A score of 1 was pale to pinkish gray in color with devoid or practically devoid marbling. A score of 5 was dark purplish red in color with moderately abundant or greater marbling. Firmness was scored as 1 = soft and watery, 2 = intermediate, and 3 = firm. Fat thickness at the 10th rib was measured perpendicular to the skin, three-fourths of the distance from the medial side of the longissimus muscle. The longissimus muscle was traced on acetate paper and the area was measured using computerized morphometric planimetry (Bioquant IV System, R & M Biometrics, Nashville, TN).

Hams, loins, picnics, and Boston butts were closely trimmed so that no more than 6 mm of fat was left on the surface. The weight of each trimmed cut was recorded.

Data were analyzed using least squares mixed-model procedures (Harvey, 1985). The basic model included the effects of farrowing season, sire within farrowing season, breed type, breed type \times farrowing season, and sire \times breed type within farrowing season. Sire within farrowing season was assumed to be random and all other effects were assumed to be fixed. The effect of farrowing season was tested against sire within farrowing season. Breed type and farrowing season \times breed type were tested against sire \times breed type within farrowing season. All other effects were tested against the residual mean square. This model was used to analyze feed consumption and feed efficiency during the nursery period.

The fixed effect of sex and its interaction with breed type and farrowing season were added to the basic model when analyzing number of nipples, preweaning survival, ADG, and BW up to 56 d of age measured on individual pigs.

Body weight, ADG, and feed efficiency measured at 28-d intervals from 70 to 154 d of age were considered to be single traits. The fixed effects of sex and age (70, 98, 126, and 154 d) and two-way interactions with other fixed effects were added to the basic model for body weight. The fixed effects of sex and interval (70 to 98, 98 to 126, and 126 to 154 d) and two-way interactions with other fixed effects were added to the

basic model for ADG, daily feed consumption, and feed efficiency. Because of limits on number of pens and the number of pigs required per pen, it was necessary to mix litters from different sires during the finishing period. Because feed consumption data were collected by pen, pen means for daily feed consumption and feed efficiency were analyzed and sire within farrowing season was not included in the model.

The covariate, weight at backfat measurement, and its interaction with breed type were added to the basic model for age and backfat thickness to estimate measurements at 99.7 kg for gilts.

The linear effect of slaughter age in days and its interaction with breed type were added to the basic model for the analyses of carcass traits.

Six pairwise linear contrasts were made among the breed type means if the *F*-test for breed type was significant ($P < .05$); contrasts were among breed types within subclass for significant interactions. For discussion of Type I error rates under these conditions, see Young (1995).

The regression of carcass traits on age provides a method of adjusting the age-constant breed type means to different end points. In this paper, the regression coefficients were used to adjust each trait to the age when the breed type would produce an average cold carcass weight of 78 kg. Young (1992b) provided a discussion of the methods to estimate the adjusted means and their associated standard errors. Tests of significance among adjusted least squares means were made by *t*-test using the adjusted sampling errors.

Results and Discussion

General. Results of the least squares analyses are presented in Tables 1 to 8. Because the objective of this experiment was to compare the four breed types, least squares means and SE are presented for the main effect of breed type for all traits and for interaction subclasses when the interactions involving breed type were significant at $P < .05$. Other main effects and nonsignificant interactions, with one exception, involving breed type will not be discussed or presented.

Traits Measured from Birth to 56 Days of Age. Table 1 presents the results of least squares analyses for number of nipples, survival to weaning, and growth to 56 d of age. Pigs that were $\frac{1}{4}$ Meishan or $\frac{1}{4}$ Fengjing averaged approximately 1.0 and .6 more nipples ($P < .05$) than $\frac{1}{4}$ Duroc or $\frac{1}{4}$ Minzhu pigs, respectively. As expected, these differences are approximately one-half as large as the differences reported by Young (1992a) comparing $\frac{1}{2}$ Meishan or $\frac{1}{2}$ Fengjing to $\frac{1}{2}$ Duroc and $\frac{1}{2}$ Minzhu. The larger number of nipples for Meishan and Fengjing relative to Minzhu is also consistent with data from the People's Republic of China (Cheng, 1983; Zhang et al., 1986).

The effect of breed type was significant for survival at birth (percentage born alive) but not for survival of pigs born alive to 14 or 28 d of age. Survival at birth was greater for Meishan crosses (98.1%) followed in order by Minzhu (97.1%), Fengjing (92.8%), and Duroc (92.1%) crosses; all differences were significant except for those between adjacent means. Young (1992a) reported no significant breed of sire effects on survival at birth of pigs produced by mating Duroc, Meishan, Fengjing, and Minzhu boars to White Composite females. Minzhu-sired pigs had a lower survival rate to 14 and 28 d of age than those sired by Meishan, Fengjing, or Duroc; the difference between Duroc and Minzhu was not significant for survival to 28 d (Young, 1992a).

The effect of breed type was significant for BW at 0, 28, and 56 d of age, but not for BW at 14 d of age. Differences among Meishan, Fengjing, and Minzhu crosses were not significant for BW at any age. Duroc crosses were heavier than the Chinese crosses at 0, 28, and 56 d of age, and all differences were significant except for the difference in 28-d BW relative to Meishan crosses. Average daily gain was greater for Duroc than for Chinese crosses from 14 to 28 d of age, but no other differences among breed groups were significant for ADG from 0 to 14, 14 to 28, or 28 to 56 d of age. In contrast to these results, Young (1992a) reported that ADG and BW from 0 to 56 d of age were generally greater for pigs sired by Meishan and Fengjing than for those sired by Duroc and Minzhu. For example, weight at 56 d of age was 16.3, 15.7, 14.6, and 14.6 kg for Meishan-, Fengjing-, Minzhu-, and Duroc-sired pigs, respectively. Young (1992a) suggested this may result from a higher level of heterosis in Chinese crosses than in Duroc crosses.

Table 2 presents the results of the analyses of ADG, daily feed consumption, and feed efficiency measured on litters from 28 to 56 d of age. The ADG means reported in Table 2 differ slightly from those in Table 1 because these means do not include data on pigs from litters that were mixed or received cross-fostered pigs. Breed type was not significant for ADG or feed efficiency but approached significance ($P = .06$) for daily feed consumption. Young (1992a) reported breed of sire to be nonsignificant for daily feed consumption but significant for ADG and feed efficiency from 28 to 56 d of age for pigs sired by Duroc, Meishan, Fengjing, and Minzhu. Meishan-sired pigs were more efficient ($P < .05$) than Duroc-sired pigs, but neither differed significantly from Fengjing- or Minzhu-sired pigs.

Traits Measured During the Finishing Period. The results of the analyses of BW and ADG measured at 28-d intervals from 70 to 154 d of age are reported in Table 3. Interactions of breed type with age and interval were significant for BW and ADG, respectively; thus, means are presented for these subclasses. Even though the interaction of breed type with sex was not significant for BW or ADG, the subclass means are presented to allow comparison to results

Table 1. Least squares means (\pm SE) and levels of significance for effect of breed type on number of nipples, survival to weaning, and average daily gain and body weight to 56 days of age

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations					
0 d	513	438	409	397	
56 d	389	394	342	340	
No. of nipples ^a	13.57 \pm .12 ^h	14.57 \pm .12 ^g	14.55 \pm .13 ^g	13.98 \pm .12 ^h	<.01
Survival, %					
at Birth ^b	92.1 \pm 2.0 ⁱ	98.1 \pm 1.9 ^g	92.8 \pm 2.0 ^{hi}	97.1 \pm 1.9 ^{gh}	.02
to 14 d ^c	88.7 \pm 1.9	93.9 \pm 1.8	92.2 \pm 2.0	92.8 \pm 1.9	.22
to 28 d ^c	86.9 \pm 2.1	92.0 \pm 2.0	91.7 \pm 2.3	90.1 \pm 2.1	.29
BW, kg					
0 d	1.30 \pm .04 ^g	1.17 \pm .04 ^h	1.19 \pm .04 ^h	1.15 \pm .04 ^h	.02
14 d ^d	3.45 \pm .11	3.35 \pm .10	3.14 \pm .12	3.24 \pm .11	.19
28 d ^e	6.35 \pm .18 ^g	5.86 \pm .17 ^h	5.56 \pm .20 ^h	5.73 \pm .18 ^h	.01
56 d ^f	13.12 \pm .34 ^g	12.56 \pm .33 ^{gh}	11.96 \pm .37 ^h	11.97 \pm .34 ^h	.04
Daily gain, g					
0 to 14 d	148 \pm 7	154 \pm 6	138 \pm 7	147 \pm 6	.31
14 to 28 d	205 \pm 7 ^g	180 \pm 7 ^h	172 \pm 8 ^h	177 \pm 7 ^h	.01
28 to 56 d	240 \pm 8	238 \pm 7	228 \pm 8	222 \pm 7	.21

^aCounted at birth on all fully formed live and dead pigs.

^bPercentage of pigs born alive.

^cPercentage of pigs born alive that survived to 14 or 28 d.

^dCreep feed provided starting at 14 d of age.

^ePigs weaned at 28 d of age.

^fEnd of nursery period.

^{g,h,i}Means within a row lacking a common superscript letter differ ($P < .05$).

reported on the previous generation of this experiment (Young, 1992a). Duroc crosses were heavier ($P < .05$) than Fengjing or Minzhu crosses at all ages and heavier ($P < .05$) than Meishan crosses at 98, 126, and 154 d of age. Meishan crosses were heavier ($P < .05$) than Fengjing and Minzhu crosses at 126 and 154 d of age. Duroc crosses grew faster ($P < .05$) than all the Chinese crosses over each 28-d interval. Meishan and Minzhu crosses grew faster ($P < .05$) than Fengjing crosses from 70 to 98 d of age. Meishan crosses grew faster ($P < .05$) than Fengjing or Minzhu crosses from 98 to 126 d of age. The Chinese crosses did not differ ($P > .05$) for ADG from 126 to 154 d of age. Young (1992a) reported Duroc-sired pigs were lighter than Meishan-sired pigs at 70, 98, and 126 d of age but were heavier at 154 d of age. Meishan-sired pigs were heavier than Fengjing- or Minzhu-sired pigs at 98, 126, and 154 d of age.

The effect of breed type was not significant for average backfat thickness of gilts at 99.7 kg (Table 3). All differences among breed type means for age at 99.7 kg were significant (Table 3). Duroc crosses were the youngest (184.5 d), followed in order by Meishan (198.0 d), Minzhu (201.1 d), and Fengjing (204.2 d) crosses. Differences among these breed types for age agree with the differences in age at 99.7 kg of gilts sired by Duroc, Meishan, Fengjing, and Minzhu (Young, 1992a).

The interaction of breed type and interval was significant for daily feed intake and the ratio of gain: feed (Table 4). The interaction of breed type and sex was not significant for feed intake but was significant for the ratio of gain:feed. Breed type was significant for both traits. Duroc crosses consumed the most feed per day over all three intervals ($P < .05$). Fengjing crosses consumed less feed than Meishan and Minzhu

Table 2. Least squares means (\pm SE) and levels of significance for effect of breed type on litter daily gain, daily feed consumption, and feed efficiency from 28 to 56 days of age

Item	Least squares means				P-value for breed type
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of litters ^a	31	33	26	28	
Daily gain, kg	.248 \pm .009	.240 \pm .008	.227 \pm .010	.240 \pm .009	.47
Daily feed consumption, kg	.502 \pm .016	.463 \pm .015	.434 \pm .018	.475 \pm .017	.06
Gain:feed	.495 \pm .011	.521 \pm .011	.529 \pm .013	.507 \pm .013	.27

^aEquivalent to number of pens.

Table 3. Least squares mean (\pm SE) and levels of significance for effect of breed type on body weight and daily gain of barrows and gilts from 70 to 154 days of age and backfat thickness and age at 99.7 kilograms for gilts

Item	Least squares means				<i>P</i> -value for breed type ^a
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of observations					
Gilts	476	484	488	480	
Barrows	364	380	384	384	
BW, kg					<.01
70 d	20.9 \pm .5 ^c	19.5 \pm .5 ^{cd}	18.6 \pm .5 ^d	18.0 \pm .5 ^d	
98 d	39.6 \pm .5 ^c	37.1 \pm .5 ^d	35.3 \pm .5 ^d	35.3 \pm .5 ^d	
126 d	62.8 \pm .5 ^c	58.1 \pm .5 ^d	55.6 \pm .5 ^e	56.0 \pm .5 ^e	
154 d	85.3 \pm .5 ^c	78.9 \pm .5 ^d	75.9 \pm .5 ^e	76.9 \pm .5 ^e	
Gilt	50.7 \pm .5	46.7 \pm .5	44.3 \pm .5	44.7 \pm .5	
Barrow	53.5 \pm .5	50.1 \pm .5	48.4 \pm .5	48.4 \pm .5	
Daily gain, g					<.01
70 to 98 d	682 \pm 8 ^c	641 \pm 8 ^d	610 \pm 8 ^e	634 \pm 8 ^d	
98 to 126 d	842 \pm 8 ^c	763 \pm 8 ^d	737 \pm 8 ^e	742 \pm 8 ^e	
126 to 154 d	806 \pm 8 ^c	739 \pm 8 ^d	726 \pm 8 ^d	739 \pm 8 ^d	
Gilt	753 \pm 7	690 \pm 7	661 \pm 7	681 \pm 7	
Barrow	800 \pm 8	740 \pm 8	720 \pm 8	729 \pm 8	
Backfat thickness ^b					
at 99.7 kg, mm	22.5 \pm .7	24.1 \pm .6	24.3 \pm .6	24.0 \pm .6	.12
Age at 99.7 kg, d	184.5 \pm 1.2 ^c	198.0 \pm 1.1 ^d	204.2 \pm 1.1 ^f	201.1 \pm 1.1 ^e	<.01

^aLevels of significance (*P*-value) for breed type effects are approximate. *P* = .08 and < .01 for breed type \times sex and breed type \times age effects, respectively, on BW. *P* = .73 and < .01 for breed type \times sex and breed type \times interval effects, respectively, on daily gain.

^bProbe backfat thickness was measured on gilts only and represents the average of three measurements taken off the midline at first, last rib, and last lumbar vertebrae; probe site \times breed type was not significant.

^{c,d,e,f}Means within a row lacking a common superscript letter differ (*P* < .05).

crosses during each interval; the difference between Fengjing and Minzhu was not significant for the interval from 126 to 154 d. The significant interaction of breed type and age for daily feed consumption resulted from changes in magnitude of differences

among breed types rather than changes in ranks of breed types. The significant interaction of breed type and interval for gain:feed was due to several changes in ranks of breed types from one interval to the next. These can be examined in Table 4. Overall (not

Table 4. Least squares means, SEM, and levels of significance for breed type effect on pen feed consumption and feed efficiency measured at 28-day intervals from 70 to 154 days of age^a

Item	Least squares means				SEM
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu	
No. of pens	18	18	18	18	
Daily feed intake, kg					
70 to 98 d	1.741 ^b	1.636 ^c	1.518 ^d	1.589 ^c	.035
98 to 126 d	2.594 ^b	2.344 ^c	2.233 ^d	2.362 ^c	.035
126 to 154 d	3.027 ^b	2.701 ^c	2.610 ^d	2.670 ^{cd}	.035
Gilt	2.326	2.062	1.954	2.033	.034
Barrow	2.582	2.392	2.287	2.382	.024
Gain/Feed					
70 to 98 d	.3864 ^b	.3936 ^{bc}	.3993 ^c	.4009 ^c	.0037
98 to 126 d	.3250 ^{bc}	.3241 ^{bc}	.3305 ^c	.3183 ^b	.0037
126 to 154 d	.2668 ^b	.2740 ^c	.2778 ^c	.2820 ^c	.0037
Gilt	.3310 ^b	.3436 ^c	.3454 ^c	.3466 ^c	.0036
Barrow	.3211 ^{bc}	.3176 ^b	.3263 ^c	.3209 ^{bc}	.0026

^a*P* < .01 for breed type effects on feed intake and gain/feed. Breed type \times interval was significant for feed intake (*P* = .02) and gain/feed (*P* = .05). Breed type \times sex was not significant for feed intake (*P* = .39) but was significant for gain/feed (*P* = .04).

^{b,c,d}Means within a row lacking a common superscript letter differ (*P* < .05).

Table 5. Number of observations and statistics of slaughter age, slaughter weight, and cold carcass weight to describe the barrows evaluated for carcass traits

Item	Breed type			
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu
No. of barrows	91	95	96	96
Age at slaughter, d				
Mean	185.9	186.1	186.8	185.7
Range	166–206	168–206	166–207	165–205
SD	12.15	12.16	12.61	12.18
Weight at slaughter, kg				
Mean	109.6	101.0	99.1	99.5
Range	75.8–144.6	72.1–136.2	75.1–133.6	71.3–130.1
SD	13.60	13.08	11.83	12.43
Cold carcass wt, kg				
Mean	79.3	71.5	70.4	71.4
Range	53.8–106.7	48.4–100.3	51.7–97.0	50.6–99.4
SD	10.98	10.22	9.11	9.43

tabulated), Duroc crosses (.3261) were less efficient ($P < .05$) than Fengjing (.3358) or Minzhu crosses (.3337); Meishan crosses were intermediate (.3306) and not significantly different from the other breed types. Among gilts, Duroc crosses were less efficient ($P < .05$) than the Chinese crosses. Among barrows, Meishan crosses were less efficient ($P < .05$) than Fengjing crosses, but neither differed significantly from the intermediate values of Duroc and Minzhu crosses. When evaluating pigs sired by Duroc, Meishan, Fengjing, and Minzhu, Young (1992a) also found significant interactions of breed with interval for these traits, but, in general, Duroc crosses consumed more feed and were more efficient than the three Chinese crosses.

Carcass Traits of Barrows. Presented in Table 5 are the number of observations for each breed type and the mean, range, and SD for age at slaughter, weight at slaughter, and cold carcass weight. These data show that slaughtering pigs with these genotypes from 165 to 207 d of age (mean age = 186 d) caused slaughter weight to range from 71.3 to 144.6 kg and cold carcass weight to range from 50.6 to 106.7 kg. The overall mean slaughter weight and carcass weight were approximately 92 and 73 kg, respectively. These weights were lighter than the corresponding weights of 111 and 78 kg reported by Young (1992b) for pigs sired by Duroc, Meishan, Fengjing, and Minzhu and slaughtered from 158 to 211 d of age (mean age = 184 d).

Table 6 presents the results of the analyses of carcass traits from the model that included slaughter age and slaughter age \times breed type as covariates. The least squares means are adjusted to a mean value of 184 d to allow comparison with data from the previous generation of this experiment (Young, 1992b). Breed type was significant for all carcass traits except fat thickness at the first rib, 10th rib, last rib, or last lumbar vertebrae, weight of leaf fat, marbling score, and firmness score. All weight measures were heavier

for Duroc than for Chinese crosses. Meishan crosses had greater ($P < .05$) longissimus muscle area than Fengjing crosses. Meishan crosses had heavier ($P < .05$) untrimmed and trimmed picnics than Minzhu crosses. Minzhu crosses had a higher ($P < .05$) color score than Fengjing and Duroc crosses; Meishan were intermediate and not significantly different from the other breed types. These results are in general agreement with the differences reported by Young (1992b) for pigs sired by Duroc, Meishan, Fengjing, and Minzhu. The differences reported here are approximately one-half the differences reported by Young (1992b), which is consistent with the halving of breed effect.

The estimates of the overall linear regression coefficient and the subclass regressions for each breed of sire for each trait are presented in Table 7. Also presented are the levels of significance for the overall regression and differences among breed type subclass regressions. These regression coefficients are reported so they can be used with the age-constant means to adjust the traits to other end points of interest. Differences among subclass regressions were not significant for any trait and approached significance ($P = .06$) only for longissimus muscle area. Young (1992b) reported significant differences among subclass regressions of age on longissimus muscle area, 10th rib fat thickness, and color score for first-cross pigs sired by Duroc, Meishan, Fengjing, and Minzhu boars. The significant effect of breed type for most carcass traits at a constant age indicates that breed types have different growth rates for carcass components. Therefore, the subclass regressions were used to adjust the breed type means to a 78-kg cold carcass weight. Although the mean carcass weight in this data set was about 73 kg, the traits were adjusted to 78 kg to allow comparison with the previous generation of this experiment (Young, 1992b).

Least squares means and approximate SE for carcass traits adjusted to a cold carcass weight of 78

Table 6. Least squares means, SE range, and levels of significance for effect of breed type on carcass traits adjusted to 184 days of age^a

Trait	Least squares means				Range of SE	P-value for breed type ^b
	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu		
Live wt, kg	108.2 ^c	100.1 ^d	98.1 ^d	98.2 ^d	1.51–1.67	<.01
Cold wt, kg	78.3 ^c	70.6 ^d	69.6 ^d	70.2 ^d	1.13–1.25	<.01
Length, cm	78.6 ^c	77.2 ^d	76.4 ^d	76.6 ^d	.50–.56	.01
Fat thickness, mm						
First rib	53.8	54.8	53.0	55.7	1.10–1.21	.35
10th rib	37.3	36.9	38.1	39.0	1.04–1.13	.45
Last rib	30.6	28.5	28.2	29.6	.74–.81	.12
Last lumbar	33.2	33.9	35.3	34.5	.92–1.00	.45
Longissimus muscle area, cm ²	28.4 ^c	25.5 ^d	23.9 ^e	24.8 ^{de}	.52–.57	<.01
Untrimmed ham, kg	8.98 ^c	7.95 ^d	7.80 ^d	7.81 ^d	.121–.133	<.01
Trimmed ham, kg	6.50 ^c	5.68 ^d	5.51 ^d	5.57 ^d	.088–.097	<.01
Untrimmed loin, kg	9.77 ^c	8.81 ^d	8.79 ^d	9.05 ^d	.180–.201	<.01
Trimmed loin, kg	6.29 ^c	5.58 ^d	5.51 ^d	5.64 ^d	.103–.114	<.01
Untrimmed butt, kg	4.36 ^c	3.94 ^d	3.81 ^d	3.96 ^d	.065–.070	<.01
Trimmed butt, kg	3.32 ^c	2.92 ^d	2.82 ^d	2.88 ^d	.048–.051	<.01
Untrimmed picnic, kg	4.10 ^c	3.66 ^d	3.55 ^{de}	3.48 ^e	.060–.065	<.01
Trimmed picnic, kg	3.29 ^c	2.89 ^d	2.79 ^{de}	2.77 ^e	.045–.048	<.01
Total untrimmed, kg	27.22 ^c	24.37 ^d	23.95 ^d	24.20 ^d	.382–.423	<.01
Total trimmed, kg	19.39 ^c	17.06 ^d	16.63 ^d	16.86 ^d	.261–.286	<.01
Belly, kg	9.09 ^c	8.16 ^d	8.11 ^d	8.09 ^d	.153–.167	<.01
Leaf fat, kg	1.09	1.08	1.07	1.07	.039–.041	.97
Marbling	2.74	2.66	2.44	2.63	.141–.156	.48
Color	2.97 ^c	3.01 ^{cd}	2.86 ^c	3.15 ^d	.065–.069	.03
Firmness	2.11	2.17	2.08	2.13	.056–.064	.68

^aThe weights of all cuts are from one side of the carcass.

^bLevels of significance for effect of breed type are approximate.

^{c,d,e}Means within a row lacking a common superscript letter differ ($P < .05$).

kg are presented in Table 8. The SE of the adjusted mean is larger for Fengjing crosses than for the other three breed types. This is primarily the result of the larger SE of the regression coefficient, but also because the mean was adjusted for more days. The larger SE for Fengjing crosses sometimes resulted in the Fengjing cross not being significantly different from Duroc even though the Fengjing cross mean was nearly equal to the Meishan and(or) Minzhu crosses. There were few significant differences among breed types when carcass traits were compared at a constant carcass weight. Duroc crosses had less fat thickness ($P < .05$) at the first rib than Meishan crosses. Duroc crosses had less fat thickness ($P < .05$) at the 10th rib than Meishan or Minzhu crosses. Duroc crosses had larger ($P < .05$) longissimus muscle area, untrimmed ham, and trimmed ham than Meishan crosses. Minzhu crosses had smaller ($P < .05$) values than Duroc for longissimus muscle area and weight of trimmed ham, untrimmed picnic, and trimmed picnic. The three Chinese crosses had more ($P < .05$) leaf fat than Duroc crosses. Minzhu crosses had a higher ($P < .05$) color score than Duroc crosses. The difference between Duroc and the Chinese crosses for weight-constant carcass traits was approximately half the difference reported by Young (1992b) for pigs that were sired by Duroc, Meishan, Fengjing, and Minzhu boars. The

similar values for weight-constant carcass traits for the three one-quarter Chinese crosses is also consistent with findings of Young (1992b).

General Discussion

Young (1992a,b) provides references and a discussion of the research published at that time comparing growth and carcass traits of purebred and first-cross Chinese pigs to purebred and first-cross domestic pigs from the United States and Europe. Those reports are consistent in finding that Chinese crosses grow more slowly and produce fatter carcasses. Those results are substantiated by more recent reports by Suzuki et al. (1991), Haley et al., (1992), Serra et al. (1992), and Lan et al. (1993).

Christian et al. (1993) evaluated the carcass traits of pigs produced by mating Duroc boars to F₁ females resulting from all possible mating combinations of Meishan, Fengjing, and Minzhu sires to Hampshire, Landrace, and Hampshire × Landrace dams. Differences among maternal grandsire breeds (Meishan, Fengjing, and Minzhu) were not significant for any carcass traits.

In the reports of Young (1992a,b), differences among pigs sired by Duroc, Meishan, Fengjing, and Minzhu resulted from differences in one-half the breed direct additive effects, specific individual heterosis

Table 7. Linear regression coefficients, their standard errors, and levels of significance for overall and subclass regression coefficients for the regression of each trait on age at slaughter

Trait	Regression coefficient					SD ^a	P-value ^b	
	Overall	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu		Overall	Subclass
Live wt, kg	.5544	.6649	.5492	.4179	.5855	8.39758	<.01	.66
Cold wt, kg	.4387	.5488	.4549	.3443	.4069	6.46402	<.01	.54
Length, cm	.1316	.1076	.1392	.0960	.1838	2.85347	<.01	.49
Fat thickness, mm								
1st rib	.1446	.1722	.2097	.1947	.0017	7.38493	.01	.49
10th rib	.2040	.1665	.2952	.1465	.2078	7.07648	<.01	.77
Last rib	.1282	.1677	.1317	.1431	.0704	5.60499	<.01	.85
Last lumbar	.1480	.2063	.1358	.1455	.1045	6.51702	<.01	.89
Longissimus muscle area, cm ²	.0690	.1549	.0373	.0898	-.0061	3.11634	<.01	.06
Untrimmed ham, kg	.0350	.0530	.0225	.0294	.0353	.76328	<.01	.23
Trimmed ham, kg	.0233	.0329	.0147	.0203	.0255	.56069	<.01	.42
Untrimmed loin, kg	.0581	.0718	.0613	.0580	.0413	.99041	<.01	.49
Trimmed loin, kg	.0292	.0364	.0299	.0308	.0197	.58027	<.01	.55
Untrimmed butt, kg	.0288	.0279	.0319	.0320	.0234	.45568	<.01	.79
Trimmed butt, kg	.0209	.0185	.0244	.0212	.0194	.35184	<.01	.85
Untrimmed picnic, kg	.0177	.0273	.0190	.0098	.0149	.37856	<.01	.20
Trimmed picnic, kg	.0135	.0180	.0134	.0107	.0118	.31008	<.01	.71
Total untrimmed, kg	.1397	.1800	.1346	.1291	.1149	2.21187	<.01	.50
Total trimmed, kg	.0869	.1058	.0823	.0830	.0764	1.58487	<.01	.80
Belly, kg	.0531	.0709	.0558	.0238	.0620	.92557	<.01	.18
Leaf fat, kg	.0177	.0181	.0217	.0128	.0180	.25592	<.01	.53
Marbling	.0005	-.0114	.0088	.0089	-.0043	.89026	.94	.64
Color	.0125	.0157	.0125	.0077	.0140	.50113	<.01	.92
Firmness	.0030	-.0040	.0077	.0062	.0022	.31157	.21	.26
Coefficient for SE	.00769	.01399	.01407	.01874	.01419			

^aStandard error of a regression coefficient can be obtained by multiplying the coefficient for SE at the bottom of the column times the SD at the end of the row. The SD is from the residual mean square.

^bLevels of significance for overall regression and for differences among breed of sire regressions.

effects, and breed paternal effects. In the present report, differences among the one-quarter Duroc, Meishan, Fengjing, and Minzhu resulted from differences in one-quarter of the breed direct additive effects, one-half of the specific individual heterosis effects, one-half of the breed maternal effects, and all of the specific maternal heterosis effects. Thus, differences among genotypes in the present study would be one-half of the differences reported by Young (1992a,b) if breed maternal, breed paternal, and maternal heterosis effects are not important. Breed maternal and maternal heterosis effects have been shown to be important for pig survival and preweaning growth and less important for postweaning growth and carcass traits (Johnson, 1980). Differences among first-cross pigs (Young, 1992a) and among one-quarter pigs in this paper were not in good agreement for traits measured before 56 d of age, reflecting the importance of maternal effects on these traits. However, differences among one-quarter pigs were approximately one-half as large as the differences among first-cross pigs (Young, 1992a,b) for postweaning growth and, especially, weight-constant carcass traits. This result was also noted by Bidanel et al. (1993), who reported growth, carcass, and meat

quality traits for pigs produced by mating Pietrain boars to 12 genetic types of sows with graded proportions of Large White and Meishan (one-half to one-eighth). Mean performance of the 12 genetic types essentially varied according to the relative proportions of Meishan and Large White genes.

Implications

Results show incorporation of females that are one-half of these Chinese breeds into a crossbreeding program will result in progeny with a significant decrease in growth rate (approximately 9% for weight at 154 d of age) and a small, nonsignificant decrease in yield of trimmed lean cuts (approximately 5%) at a constant carcass weight. The documented increased reproductive potential of these Chinese crosses must be considered when evaluating the overall profitability of the crossbreeding program. The relative value of reproduction, growth, and carcass traits varies among producers. However, these results would suggest that females containing one-half Chinese breeding may increase profits under some production and marketing scenarios.

Table 8. Least squares means (\pm approximate SE) by breed type for carcass traits adjusted to a cold carcass weight of 78 kilograms^a

Item	¼ Duroc	¼ Meishan	¼ Fengjing	¼ Minzhu
Age, d				
Live wt, kg	107.9 \pm 1.54	109.1 \pm 2.22	108.3 \pm 3.86	109.4 \pm 2.55
Length, cm	78.6 \pm .51	79.4 \pm .75	78.8 \pm 1.31	80.1 \pm .86
Fat thickness, mm				
First rib	53.8 \pm 1.14 ^c	58.2 \pm 1.80 ^b	57.6 \pm 3.29 ^{bc}	55.8 \pm 2.12 ^{bc}
10th rib	37.3 \pm 1.07 ^c	41.5 \pm 1.72 ^b	41.7 \pm 3.14 ^{bc}	42.9 \pm 2.02 ^b
Last rib	30.4 \pm .77	30.7 \pm 1.31	31.6 \pm 2.46	31.0 \pm 1.56
Last lumbar	33.1 \pm .95	36.1 \pm 1.56	38.7 \pm 2.88	36.6 \pm 1.84
Longissimus muscle area, cm ²	28.3 \pm .53 ^b	26.2 \pm .80 ^c	26.0 \pm 1.41 ^{bc}	24.7 \pm .93 ^c
Untrimmed ham, kg	8.94 \pm .125 ^b	8.35 \pm .191 ^c	8.52 \pm .343 ^{bc}	8.48 \pm .223 ^{bc}
Trimmed ham, kg	6.48 \pm .091 ^b	5.94 \pm .140 ^c	6.00 \pm .252 ^{bc}	6.05 \pm .163 ^c
Untrimmed loin, kg	9.75 \pm .184	9.81 \pm .263	10.17 \pm .457	9.85 \pm .302
Trimmed loin, kg	6.28 \pm .105	6.07 \pm .152	6.24 \pm .266	6.02 \pm .176
Untrimmed butt, kg	4.36 \pm .067	4.46 \pm .109	4.57 \pm .201	4.31 \pm .129
Trimmed butt, kg	3.32 \pm .050	3.31 \pm .083	3.32 \pm .154	3.25 \pm .099
Untrimmed picnic, kg	4.08 \pm .061 ^b	3.98 \pm .094 ^{bc}	3.79 \pm .170 ^{bc}	3.75 \pm .110 ^c
Trimmed picnic, kg	3.28 \pm .047 ^b	3.11 \pm .075 ^{bc}	3.05 \pm .137 ^{bc}	2.99 \pm .088 ^c
Total untrimmed, kg	27.13 \pm .390	26.60 \pm .573	27.05 \pm 1.009	26.39 \pm .663
Total trimmed, kg	19.36 \pm .268	18.43 \pm .403	18.62 \pm .716	18.31 \pm .468
Belly, kg	9.04 \pm .157	9.05 \pm .235	8.72 \pm .418	9.27 \pm .274
Leaf fat, kg	1.08 \pm .040 ^b	1.42 \pm .063 ^c	1.39 \pm .114 ^c	1.42 \pm .074 ^c
Marbling	2.77 \pm .145	2.79 \pm .223	2.61 \pm .401	2.57 \pm .260
Color	2.95 \pm .068 ^c	3.20 \pm .116 ^{bc}	3.05 \pm .219 ^{bc}	3.43 \pm .139 ^b
Firmness	2.12 \pm .058	2.30 \pm .083	2.22 \pm .144	2.18 \pm .095

^aThe weights of all cuts are from the left side of the carcass.

^{b,c}Means within a row lacking a common superscript letter differ ($P < .05$).

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