1992

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Abstract

Hampshire and Landrace sows and crossbreds of the two breeds were used to determine heterosis and recombination effects for milk production, milk composition, and litter traits at birth and d 21. Twelve mating types were represented in this study: two purebred, two F1, two F2, two F3, and four backcross. Information was gathered on a total of 358 litters over four farrowing seasons. Milk production was measured at d 10 and 20 of litter age according to the weigh-suckle-weigh procedure. Milk samples were collected at d 10 and 20 of litter age and evaluated for percentages of fat (PCFA), protein (PCPR), lactose (PCLA), and solids-not-fat (PCSN). The model used to evaluate litter traits at birth included main effects of mating type, parity, and farrowing season. The model used for milk production and milk composition traits included these main effects and number of pigs nursed as a covariate. Estimates of maternal genetic effects showed that Landrace females were superior to Hampshire females for number born (NB), number born alive (NBA), litter birth weight (LBW), adjusted 21-d litter weight (ALW), and milk production at d 10 of litter age (WT10). Hampshires were superior to Landrace for PCPR at d 10 of litter age and PCSN at d 10 and 20 of litter age. Heterosis effects were significant (P less than .05) for NBA (.97) and LBW (1.46 kg). Maternal heterosis effects were significant for LBW (3.94 kg; P less than .01). Epistatic recombination losses in the offspring were significant for LBW (6.80 kg; P less than .05). Differences in maternal performance of reciprocal F1 dams were generally not significant. Heterosis and recombination effects were not significant for milk production or milk composition.

Keywords

Pigs, Heterosis, Recombination, Milk Production, Milk Composition

Disciplines

Agriculture | Animal Sciences

Comments

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Published December 11, 2014

Heterosis and Recombination Effects in Hampshire and Landrace Swine: I. Maternal Traits[1]

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ABSTRACT: Hampshire and Landrace sows and crossbreds of the two breeds were used to determine heterosis and recombination effects for milk production, milk composition, and litter traits at birth and d 21. Twelve mating types were represented in this study: two purebred, two F_1, two F_2, two F_3, and four backcross. Information was gathered on a total of 358 litters over four farrowing seasons. Milk production was measured at d 10 and 20 of litter age according to the weigh-suckle-weigh procedure. Milk samples were collected at d 10 and 20 of litter age and evaluated for percentages of fat (PCFA), protein (PCPR), lactose (PCLA), and solids-not-fat (PCSN). The model used to evaluate litter traits at birth included main effects of mating type, parity, and farrowing season. The model used for milk production and milk composition traits included these main effects and number of pigs nursed as a covariate. Estimates of maternal genetic effects showed that Landrace females were superior to Hampshire females for number born (NB), number born alive (NBA), litter birth weight (LBW), adjusted 21-d litter weight (ALW), and milk production at d 10 of litter age (WT10). Hampshires were superior to Landrace for PCPR at d 10 of litter age and PCSN at d 10 and 20 of litter age. Heterosis effects were significant ($P < .05$) for NBA (.97) and LBW (1.46 kg). Maternal heterosis effects were significant for LBW (3.94 kg; $P < .01$). Epistatic recombination losses in the offspring were significant for LBW (6.80 kg; $P < .05$). Differences in maternal performance of reciprocal F_1 dams were generally not significant. Heterosis and recombination effects were not significant for milk production or milk composition.

Key Words: Pigs, Heterosis, Recombination, Milk Production, Milk Composition

J. Anim. Sci. 1992. 70:89–98

Introduction

Diversity among breeds of swine offers the opportunity to increase production efficiency in a commercial swine operation through crossbreeding. Specific crossbred combinations allow maximum utilization of heterosis and of breed differences in maternal and paternal performance.

Reproductive rate and the relative magnitude of heterosis, of recombination effects, and of breed differences in individual, maternal, and paternal performance are the key factors in determining the most advantageous method of utilizing genetic differences among breeds (Dickerson, 1973). There is an advantage in the use of crossbreeding or synthetic breeds over pure breeds when individual and maternal heterosis is large. Large breed differences in maternal or paternal performance indicate the use of some type of specific cross rather than rotational crossbreeding or synthetic breeds. If potential recombination loss is important, crossbreeding has an advantage over synthetics in utilizing breed differences.

The objectives of this study were to estimate direct and maternal effects, individual and maternal heterosis, and recombination effects for maternal performance traits for the Hampshire and Landrace breeds of swine.

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[1]Journal paper no. J-14348 of the Iowa Agric. and Home Econ. Exp. Sta., Ames. Project No. 1901.

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Received February 19, 1991.
Accepted August 12, 1991.

Materials and Methods

Data Description. Data used in this study were from an experiment involving the Hampshire (H) and Landrace (L) breeds at the Iowa State University Bilsland Memorial Research Farm. The mating design for the project was a two-breed design involving three generations of crossbreeding (Malik, 1984). Year 1 of the project consisted of the production of purebred and reciprocal F_1 crossbred litters from the mating of purebred sires and dams. Year 2 was the same as Yr 1 with F_2 crosses added. Backcross and F_3 matings were added in the 3rd yr. Mating types were produced contemporaneously within farrowing season to minimize environmental influences. A total of 358 litters from two farrowing seasons in Yr 2 and 3 was used in the analysis.

The initial breeding stock was either obtained from lines available at the Bilsland Farm or purchased from private breeders and was considered to be representative of the two breeds. An attempt was made to keep inbreeding at a minimum; otherwise, all matings were made at random. To maintain equal numbers in the mating groups, culling of sows was done at random. No sows were culled from the study because of sow or pig performance.

Purebred boars were mated to purebred and crossbred females to produce purebred, F_1, and backcross litters. Crossbred boars were mated to crossbred females to produce F_2 and F_3 mating types. Boars were replaced after each breeding season, and five boars of each breed group were used each season.

During gestation, all breeding stock was housed in open-fronted buildings located in large concrete-floored pens. Farrowing took place in farrowing pens in an environmentally controlled building. Sows and their litters were moved to individual open-fronted lactation pens with concrete floors and straw bedding at d 3 to 7 of litter age. Sows were limit-fed 1.8 to 2.3 kg/d of a 15% CP corn-soybean meal-premix diet during gestation and were given ad libitum access to the same diet during lactation. Pigs were given access to creep feed after milk production estimates were recorded at d 20 of litter age.

Litter traits evaluated were number born (**NB**), number born alive (**NBA**), and litter birth weight (**LBW**). Average pig birth weight (**ABW**) was calculated by dividing LBW by NB. Litters were weighed 20 to 22 d after farrowing and adjusted 21-d litter weights (**ALW**) were calculated using National Swine Improvement Federation (NSIF, 1987) adjustments for number of pigs nursed, parity of the dam, and age of the litter at weighing.

Milk production of the dam at d 10 (**WT10**) and 20 (**WT20**) of litter age was estimated by evaluating litter weight gain with a modified version of the weigh-suckle-weigh procedure used by Speer and Cox (1984). All pigs were removed from the sow in the morning and confined to the creep area. One hour later, the litter was weighed, placed with the sow, and allowed to nurse. At the first movement of a pig away from the sow, the pigs were gathered up, weighed, and placed back in the creep area. This procedure was repeated hourly for five consecutive hours. The nursing interval of 1 h was used to simulate normal nursing behavior of the litter during the first few weeks of lactation (Mahan et al., 1971). Weight gained by the litter during nursing was recorded and used to estimate the hourly milk production of the sow. The first 2 h were considered an adjustment period, and the data were discarded. The average of the measurements at h 3 through 5 was used for the final estimate of milk production of the dam. No adjustment was made if any pigs were observed to urinate or defecate during the nursing period or weighing process. Hourly milk production estimates that were negative were included in the data.

Milk composition was evaluated from the milk samples collected from the dams of the litters 1 h after the weigh-suckle-weigh procedure was completed. A 3-mL injection of oxytocin was given intramuscularly into the sow to stimulate milk release and a 30-mL milk sample was drawn from the functional glands of the sow. Milk samples were stored under refrigeration until they were analyzed for the following components: percentage of fat (**PCFA**), percentage of protein (**PCPR**), percentage of lactose (**PCLA**), and percentage of solids-not-fat (**PCSN**). Samples were collected at d 10 and 20 of litter age.

Milk samples were tested with a Multispec 2 instrument (Foss Food Technology, Eden Prairie, MN) equipped with infrared light. Instrument calibrations were made using wet chemistry results from representative samples. Samples were analyzed for solids according to the Mojonnier method, for fat according to the Babcock test, for lactose using a HPLC procedure, and for protein (AOAC, 1980; Richardson, 1985). Percentage of solids-not-fat was obtained by difference.

Sows were weighed within 24 h after farrowing and again at 21 d of litter age. These data were used to determine changes in sow weight during lactation.

Statistical Analysis. The theory for estimating genetic parameters from crossbreeding data was proposed by Dickerson (1969, 1973). The genetic parameters estimated in this study are as follows:

Table 1. Equations for expected contributions of genetic effects in purebred Hampshire and Landrace and their crosses[a]

PB	$HH = g^o_H + g^M_H$
	$LL = g^o_L + g^M_L$
F_1	$HL = 1/2g^o_H + 1/2g^o_L + g^M_L + h^o_{HL}$
	$LH = 1/2g^o_H + 1/2g^o_L + g^M_H + h^o_{HL}$
F_2	HL^2 or $LH^2 = 1/2g^o_H + 1/2g^o_L + 1/2g^M_H + 1/2g^M_L + 1/2h^o_{HL} + h^M_{HL} + 1/2r^o_{HL}$
F_3	HL^3 or $LH^3 = 1/2g^o_H + 1/2g^o_L + 1/2g^M_H + 1/2g^M_L + 1/2h^o_{HL} + 1/2h^M_{HL} + 1/2r^o_{HL} + 1/2r^M_{HL}$
B_1[b]	H(HL) or H(LH) $= 3/4g^o_H + 1/4g^o_L + 1/2g^M_H + 1/2g^M_L + 1/2h^o_{HL} + h^M_{HL} + 1/4r^o_{HL}$
	L(HL) or L(LH) $= 1/4g^o_H + 3/4g^o_L + 1/2g^M_H + 1/2g^M_L + 1/2h^o_{HL} + h^M_{HL} + 1/4r^o_{HL}$

[a]The first letter represents breed of sire, and the second letter represents breed of dam; H = Hampshire, L = Landrace.
[b]B_1 = backcross mating of paternal breed × F_1.

g^o = average direct effects of the offspring, g^M = maternal genetic effects, h^o = heterosis in the crossbred progeny, h^M = heterosis in the crossbred dam, r^o = recombination losses in the offspring, and r^M = recombination losses in the dam.

Dickerson (1969) described individual heterosis as the deviation from parental averages "due to increased average heterozygosity of F_1 crossbreds from A males × B females, or reciprocals, including any nonallelic interaction of A with B gametes." Maternal heterosis is the result of the dam being a crossbred. Recombination losses occur in the F_2 and backcross generations due to segregation and recombination of genes brought together from the two purebred parents in the F_1. The r parameters measure deviations from the linear association of heterosis with the degree of heterozygosity and the coefficients describe the average fraction of independently segregating pairs of loci in gametes from both parents, which are expected to be nonparental combinations (Dickerson, 1973).

Equations for the expected contribution of genetic effects in purebred H and L and their crosses are presented in Table 1 (Malik, 1984). Estimation of genetic effects (Table 2) is made by mating-type comparisons in which the mean of a crossbred type represents the value of the reciprocal crosses in that type (Malik, 1984).

Several models were used to analyze the data according to the GLM procedure of SAS (1985). All two- and three-factor interactions of main effects were included in the initial analysis of the data and were not significant and thus were excluded from the final models. Linear contrasts among least squares means for the various traits were calculated to provide comparisons of interest, regardless of orthogonality or linear independence.

Litter traits of NB, NBA, LBW, ABW, and sow weight 24 h after farrowing were analyzed according to the following model:

$$Y_{ijkl} = \mu + m_i + p_j + r_k + e_{ijkl}$$

where Y_{ijkl} = observation of the l^{th} litter in the k^{th} farrowing season in the j^{th} parity of the i^{th} mating type, μ = overall mean, m_i = fixed effect common to the i^{th} mating type, p_j = fixed effect common to the j^{th} parity, r_k = fixed effect common to the k^{th} farrowing season, and e_{ijkl} = random residual error with mean zero and variance σ^2_e.

A covariate for the linear regression of Y on the number of pigs nursed was added to this model for the traits of milk production and milk composition at d 10 and 20 of litter age and for sow weight change from 24 h after farrowing to 21 d of litter age. The model for ALW included the main effects listed above and covariates for number nursed, sow weight 24 h after farrowing, sow weight change during lactation, and the interaction of

Table 2. Estimation of genetic effects

Effects[a]	Mating type comparison[b]
$g^o_H - g^o_L$	$\overline{HH} - \overline{LL} + \overline{HL} - \overline{LH}$
$g^M_H - g^M_L$	$\overline{LH} - \overline{HL}$
h^o_{HL}	$\overline{F}_1 - \overline{P}$
h^M_{HL}	$2\overline{B}_1 - \overline{F}_2 - 1/2(\overline{P} + \overline{F}_1)$
r^o_{HL}	$4(\overline{F}_2 - \overline{B}_1)$
r^M_{HL}	$2\overline{F}_3 + 2\overline{B}_1 - 3\overline{F}_2 - 1/2(\overline{F}_1 + \overline{P})$

[a]g^o = Average direct effects of the offspring, g^M = maternal genetic effects, h^o = heterosis in the crossbred progeny, h^M = heterosis in the crossbred dam, r^o = recombination loss in the offspring, and r^M = recombination loss in the dam. H = Hampshire, L = Landrace.
[b]Bar over designation represents its mean. $\overline{P}$ = (HH + LL)/2; B_1 = backcross mating of parental breed × F_1.

Table 3. Least squares means and standard errors for litter traits[a] at birth by mating type and parity

Source	No.	NB	NBA	LBW, kg	ABW, kg
$\bar{X}$	358	10.75 ± .16	10.13 ± .15	17.56 ± .25	1.67 ± .02
Mating type[b]		**	**	**	—
H × H	42	9.87 ± .46	9.37 ± .43	16.11 ± .65	1.66 ± .04
H × L	33	12.44 ± .52	11.85 ± .48	20.74 ± .75	1.70 ± .05
L × H	32	9.99 ± .52	9.50 ± .49	16.66 ± .74	1.69 ± .05
L × L	31	10.83 ± .53	10.04 ± .49	18.37 ± .75	1.75 ± .05
H × HL	15	11.04 ± .77	10.90 ± .72	19.68 ± 1.10	1.81 ± .07
H × LH	15	11.37 ± .77	10.43 ± .72	19.03 ± 1.10	1.72 ± .07
L × HL	15	13.17 ± .79	12.90 ± .74	21.95 ± 1.12	1.69 ± .08
L × LH	10	11.73 ± .95	10.81 ± .88	21.18 ± 1.35	1.78 ± .09
HL^2	59	11.39 ± .40	10.71 ± .38	18.96 ± .57	1.71 ± .04
LH^2	63	11.12 ± .39	10.25 ± .36	18.06 ± .55	1.68 ± .04
HL^3	22	11.61 ± .70	10.82 ± .65	17.94 ± .99	1.57 ± .07
LH^3	21	9.73 ± .72	9.05 ± .67	16.60 ± 1.02	1.76 ± .07
Parity		*	*	**	**
1	214	10.47 ± .23	9.91 ± .22	16.74 ± .33	1.63 ± .02
2	100	11.08 ± .32	10.61 ± .30	19.02 ± .46	1.76 ± .03
3	44	12.02 ± .52	11.14 ± .49	20.32 ± .74	1.74 ± .05

[a]NB = number born, NBA = number born alive, LBW = litter birth weight, and ABW = average pig birth weight.

[b]The first letter represents breed of sire and the second letter represents breed of dam; H = Hampshire, L = Landrace; HL and LH are F_1 matings; HL^2 and LH^2 are F_2 matings; HL^3 and LH^3 are F_3 matings.

*$P < .05$.

**$P < .01$.

mating type and the regression of Y on sow weight change during lactation.

Sire was not included in the above models because genetic group effects, not individual sire effects, were desired. Ignoring sires could cause the reported standard errors to be underestimated. In reality, sires contributed unequally to the average of the genetic group because of differences in conception rate and because purebred sires were used across mating types to sire purebred, F_1, and backcross litters.

Results and Discussion

Litter Traits

Least squares means for litter traits at birth are presented in Table 3, and estimates of genetic effects for these traits are listed in Table 4.

Main Effects. Purebred L females farrowed larger (1.51 pigs) and heavier (3.17 kg) litters than purebred H females, and L litters were heavier (2.26 kg) at birth than H litters. Litters from crossbred sows were 1.08 kg heavier at birth than litters from purebred sows. Litters sired by purebred boars, however, were 1.20 kg heavier than those sired by crossbred boars. Comparisons of reciprocal F_1 dams indicated that there was little difference between HL and LH dams for the litter traits measured except for NBA. Litters from HL dams were 1.01 pigs larger ($P < .10$) at birth than those from LH dams. Parity was a significant source of variation for NB, NBA, LBW, and ABW. Second- and third-parity females farrowed larger and heavier litters and heavier individual pigs than did first-litter gilts.

Parameter Estimates. Estimates of maternal genetic effects showed that L sows were superior to H sows for NB, NBA, and LBW. Individual heterosis estimates of .86 for NB, .97 for NBA, and 1.46 kg for LBW are higher than estimates reported by Sellier (1976), Young et al. (1976), and Johnson (1980). The estimates in this study indicate a definite advantage for purebred females raising F_1 litters over those raising purebred litters for these traits. This may be due in part to the effect of the sire of the litter.

Maternal heterosis was significant for LBW ($P < .01$) and NBA ($P < .10$), indicating the superiority of crossbred females to purebred females for these traits. These maternal heterosis estimates of 22.9% for LBW and 19.2% for NBA may have implications for producers in the development of specific maternal crosses. Jungst and Kuhlers (1984) reported maternal heterosis estimates of 2.49 kg for LBW and .82 pigs for NBA and concluded that H females would perform well on the maternal side of a crossbreeding system. Other researchers have also reported an advantage for F_1 females over purebred females for LBW (Johnson and Omtvedt, 1973; Johnson et al., 1978; Schneider et al., 1982). A significant individ-

Table 4. Estimates of genetic effects for litter traits[a] at birth

Effect[b]	NB	NBA	LBW, kg	ABW, kg
$g_H^o - g_L^o$	1.50 ± .99	1.68 ± .92†	1.83 ± 1.41	−.08 ± .10
$g_H^M - g_L^M$	−2.45 ± .72**	−2.35 ± .67**	−4.08 ± 1.03**	−.01 ± .07
h_{HL}^o	.86 ± .49†	.97 ± .46*	1.46 ± .70*	−.01 ± .05
%	8.3	10.0	8.5	−.44
h_{HL}^M	1.62 ± 1.01	1.86 ± .95†	3.94 ± 1.44**	.11 ± .10
%	15.6	19.2	22.9	6.22
r_{HL}^o	−2.29 ± 2.26	−3.13 ± 2.11	−6.80 ± 3.22*	−.22 ± .22
r_{HL}^M	.44 ± 1.88	.77 ± 1.76	1.45 ± 2.68	.04 ± .18

[a]NB = number born, NBA = number born alive, LBW = litter birth weight, and ABW = average pig birth weight.

[b]g^o = Average direct effects of the offspring, g^M = maternal genetic effects, h^o = heterosis in the crossbred progeny, h^M = heterosis in the crossbred dam, r^o = recombination loss in the offspring, and r^M = recombination loss in the dam. H = Hampshire, L = Landrace.

† $P < .10$.

*$P < .05$.

**$P < .01$.

ual recombination loss for LBW indicates that purebred boars sired heavier litters than did F_1 boars when both groups were mated to F_1 females. Recombination estimates for NB and NBA were in the same direction but were not significant.

Milk Production

Least squares means for three estimates of milk production are presented in Table 5. Estimates of genetic effects for these traits are given in Table 6.

Main Effects. Litters from crossbred dams at d 21 were 3.61 kg heavier ($P < .01$) than litters from purebred females at the same age. Kuhlers et al. (1981) reported that litters from crossbred L sows were heavier at d 21 ($P < .01$) than those from purebred L sows. Landrace sows nursing purebred or crossbred litters in this study were superior (4.73 kg) to H sows for ALW. Significant linear regressions for ALW on sow weight after farrowing and on number of pigs nursed indicated a positive relation between these traits.

Milk production estimates at d 10 and 20 in this study were similar to those reported by Lewis et al. (1978) and by Speer and Cox (1984) at d 14 and 20 of lactation. Larger estimates were reported by Mahan et al. (1971) at d 13 and 21 and by Boyd et al. (1982) at d 12 and 19. The effect of mating type was not significant for WT10 or WT20, and parity differences were significant for WT10 but not for WT20. Second- and third-parity females were superior to first-litter gilts for WT10. Speer and Cox (1984) reported a significant difference between first- and second-parity females for milk production estimates on d 14 of lactation.

The linear regression of milk production on number nursed was significant at both d 10 and 20 of litter age. Coefficients were 15 g of milk per hour at d 10 and 14 g of milk per hour at d 20 for every pig increase in number nursed.

Parameter Estimates. Maternal genetic effects were significant ($P < .05$) for ALW and WT10, indicating that L sows were superior to H sows. Estimates of maternal heterosis and maternal recombination effects for ALW approached significance ($P < .10$). The maternal heterosis estimate of 6.34 kg in this study is similar to values reported by Johnson and Omtvedt (1973), by Schneider et al. (1982), and by Johnson et al. (1978) and is lower than the value of 8.66 kg reported by Jungst and Kuhlers (1984). These researchers used data from litters that were standardized at birth. Maternal heterosis estimates for WT10 and WT20 were small and not important.

Sow Weight Change

Least squares means for sow weight 24 h after farrowing (PFW) and lactation weight change (WTCH) are listed in Table 7.

Main Effects. Crossbred sows weighed more (PFW) than purebred sows after farrowing and H sows weighed more than L sows ($P < .01$). As expected, sows were heavier with each succeeding lactation.

Main effects of mating type and parity were not significant ($P < .05$) for WTCH, although linear contrasts showed that crossbred sows lost more weight during the first 21 d of lactation than did purebred sows. The linear regression of WTCH on number of pigs nursed was significant ($P < .01$) and indicates that sows nursing larger litters lost more weight during the first 3 wk of lactation. Omtvedt et al. (1966) and Fahmy et al. (1971) reported that sow weight loss during lactation was associated with larger and heavier litters at weaning.

Milk Composition

Least squares means for the four milk components evaluated at d 10 and 20 of litter age are presented in Tables 8 and 9, respectively. Estimates of genetic parameters are given in Table 10.

Mean values for PCFA, PCPR, and PCLA in this study are similar to those reported by Schuld and Bowland (1968). O'Grady et al. (1973) found similar values for PCPR but lower levels than those of this study for PCFA and PCLA. Perrin (1954) and Rook and Witter (1968) reported lower values for PCLA and higher values for PCFA and PCPR. Miller et al. (1971) found similar values for PCPR and lower values for PCFA and PCLA. Jenness (1985) listed average values for swine milk for fat (6.8%) and for lactose (5.5%).

Comparing percentages of components at two stages of lactation revealed that fat decreased, protein and lactose increased slightly, and solids-not-fat was nearly equal as lactation advanced from d 10 to 20. These findings agree with the findings of Braude et al. (1947), Pond et al. (1962), and Rook and Witter (1968), who reported that PCFA decreased and PCPR increased from the 1st to the 3rd wk of lactation. Perrin (1954) and Colenbrander et al. (1967) found that PCPR decreased, PCFA increased, and PCLA remained the same as lactation advanced from wk 1 to wk 3. Noblet and Etienne (1986) reported that PCLA increased and PCFA and PCPR decreased as days of lactation advanced.

Main Effects. Milk from H dams nursing either purebred or crossbred pigs was consistently higher in PCPR than milk from L dams at both d 10 and 20 ($P < .01$). A corresponding superiority ($P < .01$) in PCSN was expected because protein makes up a large part of the solids in milk. Fahmy (1972) reported that milk from H females was higher in PCPR than milk from sows of the Yorkshire, L, Lacombe, Duroc, Berkshire, or Large

Table 5. Least squares means and standard errors for adjusted 21-day litter weight and milk production at 10 and 20 days of litter age by mating type and parity

Source	No.	ALW[a], kg	WT10[b], g/h	WT20[c], g/h
$\overline{X}$	341	54.24 ± 0.48	219 ± 7	245 ± 11
Mating type[d]		**	—	—
H × H	39	49.58 ± 1.27	211 ± 22	294 ± 33
H × L	31	52.66 ± 1.33	267 ± 24	258 ± 37
L × H	31	50.62 ± 1.36	197 ± 24	230 ± 37
L × L	31	53.12 ± 1.40	212 ± 24	226 ± 37
H × HL	15	56.08 ± 2.12	177 ± 36	192 ± 54
H × LH	15	55.51 ± 1.98	241 ± 36	263 ± 54
L × HL	14	57.88 ± 2.20	239 ± 37	249 ± 56
L × LH	10	52.39 ± 2.39	249 ± 44	274 ± 67
HL^2	56	56.58 ± 1.12	251 ± 19	236 ± 28
LH^2	58	54.48 ± 1.05	200 ± 18	234 ± 27
HL^3	21	54.48 ± 1.81	264 ± 32	215 ± 50
LH^3	20	56.49 ± 1.93	273 ± 33	338 ± 50
Parity		—	**	—
1	202	54.06 ± .70	206 ± 11	237 ± 17
2	95	55.53 ± .92	261 ± 15	265 ± 23
3	44	52.88 ± 1.64	229 ± 24	250 ± 37
Linear regressions				
No. nursed	—	1.59 ± .23**	15 ± 4**	14 ± 6*
PFW[e]	—	.05 ± .02*	—	—
WTCH[f]	—	−.03 ± .16	—	—

[a]ALW = adjusted 21-d litter weight.
[b]WT10 = milk production at 10 d of litter age.
[c]WT20 = milk production at 20 d of litter age.
[d]The first letter represents breed of sire, and the second letter represents breed of dam; H = Hampshire, L = Landrace; HL and LH are F_1 matings; HL^2 and LH^2 are F_2 matings; HL^3 and LH^3 are F_3 matings.
[e]PFW = sow weight 24 h postfarrowing.
[f]WTCH = lactation weight change from 24 h postfarrowing to 21 d of litter age.
*$P < .05$.
**$P < .01$.

Table 6. Estimates of genetic effects for adjusted 21-day litter weight and milk production at 10 and 20 days of litter age

Effect[a]	ALW[b], kg	WT10[c], g/h	WT20[d], g/h
$g_H^o - g_L^o$	.25 ± 2.93	68 ± 46	97 ± 69
$g_H^M - g_L^M$	−4.85 ± 2.31*	−70 ± 33*	−28 ± 51
h_{HL}^o	1.90 ± 1.47	21 ± 23	−16 ± 35
%	3.7	9.7	6.2
h_{HL}^M	6.34 ± 3.30†	6 ± 47	2 ± 72
%	12.3	2.8	.9
r_{HL}^o	−8.75 ± 7.54	−4 ± 105	−39 ± 160
r_{HL}^M	10.77 ± 5.88†	92 ± 87	85 ± 133

[a]g^o = Average direct effects of the offspring, g^M = maternal genetic effects, h^o = heterosis in the crossbred progeny, h^M = heterosis in the crossbred dam, r^o = recombination loss in the offspring, and r^M = recombination loss in the dam. H = Hampshire, L = Landrace.
[b]ALW = adjusted 21-d litter weight.
[c]WT10 = milk production at 10 d of litter age.
[d]WT20 = milk production at 20 d of litter age.
†$P < .10$.
*$P < .05$.

Black breeds. Milk from crossbred dams had a greater PCLA than did milk from purebred dams at both d 10 and 20 of litter age.

The effect of parity was not significant for any of the milk components studied. This finding agrees with the findings of Klobasa et al. (1987) and Heidebrecht et al. (1951), who found no relation between milk components and parity of the dam. Lodge (1959) reported that milk from first-litter gilts was higher in PCLA and lower in PCFA and PCPR. O'Grady et al. (1973) found that milk from first-litter gilts on d 24 of lactation was slightly higher in PCFA and PCPR and nearly equal in PCLA and total solids compared with milk from second-parity sows. Johnston et al. (1986) reported that milk from second-parity sows was lower in PCFA and nearly equal in PCPR to milk from first-litter gilts.

The linear regressions of PCPR at d 10 and 20 and PCFA and PCSN at d 20 on number nursed were significant ($P < .01$). The negative coefficients indicated that component percentages decreased as the number of pigs nursed increased.

Parameter Estimates. Estimates of maternal genetic effects for PCPR and PCSN in Table 10 are consistent with results of additional mating type comparisons that were made. Milk from H sows was consistently higher in PCPR than milk from L sows.

Heterosis and recombination estimates were generally small and not significant for all four milk components at both stages of lactation. Maternal heterosis percentages ranged from −2.6 to 4.1%; the largest percentage was that of lactose at d 20 of litter age.

Implications

Heterosis estimates for milk production of the dam according to weigh-suckle-weigh procedures and for milk composition traits were small and not significant. This finding indicates little crossbreeding advantage for these traits. Milk from Hampshire females was higher in percentage of protein and percentage of solids-not-fat than milk from Landrace females, a finding that may warrant further research in the areas of nutrient conversion and utilization. Estimates of recombination loss were generally not significant. This finding indicates that there should be little difference in heterosis as measured and expected heterosis in a particular cross. Producers should expect similar performance from Hampshire × Landrace or Landrace × Hampshire females because differences in maternal performance were generally not important.

Table 7. Least squares means and standard errors for sow weight 24 hours postfarrowing and lactation weight change from 24 hours postfarrowing to 21 days of litter age by mating type and parity

Source	No.	PFW[a], kg	WTCH[b], kg
$\bar{X}$	341	186.9 ± 1.8	9.9 ± .7
Mating type[c]		**	—
H × H	39	202.6 ± 3.5	8.6 ± 2.0
H × L	31	187.0 ± 4.0	8.7 ± 2.2
L × H	31	202.0 ± 4.0	9.9 ± 2.2
L × L	31	186.5 ± 4.0	6.0 ± 2.2
H × HL	15	213.1 ± 5.8	17.0 ± 3.2
H × LH	15	212.2 ± 5.8	12.0 ± 3.2
L × HL	14	223.0 ± 6.2	15.2 ± 3.4
L × LH	10	204.2 ± 7.2	9.7 ± 3.9
HL^2	56	206.0 ± 3.1	12.1 ± 1.7
LH^2	58	203.0 ± 2.9	10.5 ± 1.6
HL^3	21	199.5 ± 5.3	12.5 ± 2.9
LH^3	20	209.7 ± 5.4	9.6 ± 3.0
Parity		**	†
1	202	171.7 ± 1.8	11.1 ± 1.0
2	95	202.9 ± 2.5	8.2 ± 1.4
3	44	237.6 ± 4.0	13.7 ± 2.1
Linear regressions			
No. nursed	—	—	1.6 ± .4**

[a]PFW = sow weight 24 h postfarrowing.
[b]WTCH = lactation weight change from 24 h postfarrowing to 21 d of litter age.
[c]The first letter represents breed of sire and the second letter represents breed of dam; H = Hampshire, L = Landrace; HL and LH are F_1 matings; HL^2 and LH^2 are F_2 matings; HL^3 and LH^3 are F_3 matings.
†$P < .10$.
**$P < .01$.

Table 8. Least squares means and standard errors for milk components[a] at 10 days of litter age by mating type and parity

Source	No.	PCFA	PCPR	PCLA	PCSN
$\bar{X}$	337	6.73 ± .08	4.96 ± .03	6.38 ± .03	15.58 ± .22
Mating type[b]		—	*	—	—
H × H	38	6.83 ± .26	5.22 ± .09	6.32 ± .06	15.69 ± .19
H × L	32	6.92 ± .29	4.75 ± .10	6.47 ± .07	14.94 ± .21
L × H	29	6.74 ± .29	5.18 ± .10	6.37 ± .07	15.60 ± .22
L × L	31	6.54 ± .29	4.95 ± .10	6.31 ± .07	15.09 ± .21
H × HL	15	6.58 ± .42	4.86 ± .15	6.52 ± .10	15.02 ± .31
H × LH	14	6.38 ± .44	5.02 ± .15	6.49 ± .10	15.01 ± .32
L × HL	15	6.73 ± .44	5.02 ± .15	6.41 ± .10	15.26 ± .31
L × LH	10	6.94 ± .52	4.80 ± .18	6.55 ± .12	15.20 ± .38
HL^2	52	6.68 ± .22	4.95 ± .08	6.43 ± .05	15.44 ± .17
LH^2	58	6.39 ± .21	4.90 ± .08	6.46 ± .05	15.19 ± .16
HL^3	22	7.10 ± .38	5.02 ± .14	6.42 ± .09	15.60 ± .28
LH^3	21	6.42 ± .39	4.84 ± .14	6.54 ± .09	15.37 ± .28
Parity					
1	196	6.84 ± .13	4.91 ± .05	6.40 ± .03	15.07 ± .09
2	97	6.55 ± .18	5.01 ± .06	6.44 ± .04	15.29 ± .13
3	44	6.67 ± .29	4.96 ± .10	6.48 ± .07	15.48 ± .21
Linear regressions					
No. nursed	—	−.06 ± .05	−.04 ± .02**	.01 ± .01	−.04 ± .03

[a]PCFA = percentage of fat, PCPR = percentage of protein, PCLA = percentage of lactose, and PCSN = percentage of solids-not-fat.

[b]The first letter represents breed of sire and the second letter represents breed of dam; H = Hampshire, L = Landrace; HL and LH are F_1 matings; HL^2 and LH^2 are F_2 matings; HL^3 and LH^3 are F_3 matings.

*$P < .05$.

**$P < .01$.

Table 9. Least squares means and standard errors for milk components[a] at 20 days of litter age by mating type and parity

Source	No.	PCFA	PCPR	PCLA	PCSN
$\bar{X}$	354	6.35 ± .07	5.05 ± .03	6.45 ± .03	15.59 ± .22
Mating type[b]		—	*	**	**
H × H	41	6.26 ± .20	5.36 ± .08	6.37 ± .07	15.82 ± .17
H × L	32	6.53 ± .23	5.03 ± .09	6.27 ± .08	15.03 ± .19
L × H	32	6.13 ± .23	5.19 ± .09	6.43 ± .07	15.56 ± .19
L × L	31	6.08 ± .23	4.94 ± .09	6.31 ± .08	15.03 ± .19
H × HL	15	5.67 ± .33	4.92 ± .14	6.72 ± .11	14.94 ± .27
H × LH	15	6.06 ± .33	5.12 ± .14	6.62 ± .11	15.49 ± .27
L × HL	15	6.83 ± .34	5.12 ± .14	6.52 ± .11	15.75 ± .28
L × LH	10	6.79 ± .41	5.23 ± .17	6.43 ± .14	16.23 ± .34
HL^2	59	6.19 ± .17	4.96 ± .07	6.54 ± .06	15.37 ± .14
LH^2	62	6.37 ± .17	5.04 ± .07	6.54 ± .06	15.52 ± .14
HL^3	21	6.37 ± .31	4.91 ± .13	6.61 ± .10	15.16 ± .25
LH^3	21	6.32 ± .31	5.04 ± .13	6.56 ± .10	15.76 ± .25
Parity					
1	212	6.43 ± .10	5.01 ± .04	6.44 ± .03	15.33 ± .08
2	98	6.17 ± .14	5.13 ± .06	6.51 ± .05	15.57 ± .12
3	44	6.30 ± .23	5.08 ± .09	6.53 ± .07	15.53 ± .19
Linear regressions					
No. nursed	—	−.12 ± .04**	−.04 ± .02**	.00 ± .01	−.09 ± .03**

[a]PCFA = percentage of fat, PCPR = percentage of protein, PCLA = percentage of lactose, and PCSN = percentage of solids-not-fat.

[b]The first letter represents breed of sire and the second letter represents breed of dam; H = Hampshire, L = Landrace; HL and LH are F_1 matings; HL^2 and LH^2 are F_2 matings; HL^3 and LH^3 are F_3 matings.

*$P < .05$.

**$P < .01$.

Table 10. Estimates of genetic effects for milk components[a] at 10 and 20 days of litter age

Effect[b]	Day	PCFA	PCPR	PCLA	PCSN
$g_H^o - g_L^o$	10	.48 ± .55	−.15 ± .19	.11 ± .13	−.06 ± .40
	20	.58 ± .43	.26 ± .18	−.10 ± .14	.27 ± .35
$g_H^M - g_L^M$	10	−.18 ± .40	.43 ± .14**	−.10 ± .09	.65 ± .30*
	20	−.40 ± .31	.16 ± .13	.16 ± .10	.53 ± .26*
h_{HL}^o	10	.15 ± .27	−.12 ± .10	.11 ± .06†	−.12 ± .20
%		2.2	−2.3	1.7	−.8
	20	.16 ± .21	−.04 ± .07	.01 ± .07	−.13 ± .18
		2.6	−.8	.2	−.8
h_{HL}^M	10	.02 ± .56	−.10 ± .20	.18 ± .13	−.40 ± .41
%		.4	−1.9	2.8	−2.6
	20	.14 ± .44	.07 ± .18	.26 ± .15†	.40 ± .36
		2.3	1.4	4.1	2.6
r_{HL}^o	10	−.49 ± 1.25	−.01 ± .44	−.21 ± .29	.76 ± .91
	20	−.21 ± .98	−.41 ± .41	−.13 ± .32	−.62 ± .80
r_{HL}^M	10	.47 ± 1.04	−.08 ± .37	.25 ± .24	−.05 ± .75
	20	.27 ± .82	.03 ± .34	.35 ± .27	.43 ± .67

[a]PCFA = percentage of fat, PCPR = percentage of protein, PCLA = percentage of lactose, and PCSN = percentage of solids-not-fat.
[b]g^o = average direct effects of the offspring, g^M = maternal genetic effects, h^o = heterosis in the crossbred progeny, h^M = heterosis in the crossbred dam, r^o = recombination loss in the offspring, and r^M = recombination loss in the dam. H = Hampshire, L = Landrace.
†$P < .10$.
*$P < .05$.
**$P < .01$.

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