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Research article

Comparison of an extended lactation period and lactation performance among Meishan (M), Yorkshire (Y), and Meishan/Yorkshire (M/Y) crossbred females for use in production as possible nurse sows

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Abstract: Six Meishan (M), nine Yorkshire (Y), and ten Meishan/Yorkshire (M/Y) crossbred first- and second-parity sows were used to investigate the influence of genotype on lactation length, piglet growth, and milk composition to develop a strategy for using nurse sows. Litter size was standardized to 10 piglets between 5 and 7 days of lactation. A new set of 1-week-old piglets was cross-fostered onto each female at the end of each 3-week period. Subsequent litter size depended on the number of piglets each female was able to support in the previous litter. Mean days of lactation for M, M/Y, and Y were 50.2, 72.8, and 64.5, respectively. Average litter size declined in all three genotypes by week 6 of lactation. Mean litter weight gain/week of lactation for Y (11.3 kg) and M/Y (12.2 kg) was greater than for M (7.65 kg). No difference in milk fat percentage was observed among genotypes. Milk protein percentage decreased from week l to week 2, then increased linearly for the rest of the lactation. These results suggested that Y and M/Y sows would make better nurse sows than purebred M sows.

Keywords: Meishan; Yorkshire; Meishan X Yorkshire crossbreed; milk production; suckling period

1. Introduction

Lactation is an essential part of any swine production enterprise. To achieve maximum output, sows are expected to produce large litters and then nurse them to an adequate weaning weight. Recent advances in animal breeding and selection have improved litter sizes and birth weights in commercial practice [1–6]. However, little progress has been made toward increasing milk production and the female's ability to handle the increase in piglet numbers. In 1960 [7], average milk yield in sows was estimated at 5–8 kg per day over an 8-week lactation period, or at 6–9+ kg per day over a 4-week lactation period, with peak lactation occurring at 18.7 days [8]. Estimates of female milk yield had not increased substantially by the late 1990s [8,9]. Piglets need, on average, 3.92, 4.55, and 4.77 g of milk per gram of piglet gain on weeks 1, 2, and 3, respectively [10,11], though weight gains are subject to many variables [11–13]. Further, sows may be at the limit of how much feed they can eat in order to make milk [14]. Recently, strategies have begun to be developed to handle sows with larger litters [3,5,15–18]. The Meishan breed has been shown to have larger litters and lower mortalities than Western breeds [19,20], so they may provide improved maternal traits in cross-breeding systems [21,22].

It was previously shown that nurse sows can be used along with or in place of non-nurse sows [15,23,24]. Chinese Meishan sows have been observed to repeatedly adopt and rear underdeveloped 3-week-old piglets and to extend lactations from 20–22 weeks and rear up to 64 additional piglets [25]. The sows could raise their own litters to 3 weeks of age, which is when many commercial producers wean the piglets, and small piglets from other sows could be cross-fostered. This new litter could be suckled for an additional 2 weeks, resulting in a 5-week total lactation. The sows in these production systems have shown an overall increase in number of piglets weaned.

The purpose of the present study was to evaluate extended lactation, up to 8 weeks, in Meishan, Yorkshire, and Meishan/Yorkshire sows to assess their potential for use in a nurse sow program.

2. Materials and methods

2.1. On-farm management

Over the 16-month period of this study, six Meishan (M), nine Yorkshire (Y), and ten Meishan/Yorkshire (M/Y) crossbred sows were used. All animals were first-parity sows, except for four Y sows, which were second parity. No statistical difference ($P > 0.05$) was found in performance among the parities of the five first-parity Y sows and the four second-parity Y sows. Therefore, the data for Y was pooled over the two parties. All lactating animals will be referred to as sows for this study. Sows were housed at the Moorman Swine Research Farm at the University of Illinois in Urbana, Illinois. Farm hygiene includes vaccinating gilts against porcine parvovirus (PPV), erysipelas caused by *Erysipelothrix rhusiopathiae*, leptospirosis caused by *L. bratislava*, *L. canicola*, *L. grippotyphosa*, *L. hardjo*, *L. icterohaemorrhagiae and L. pomona*, *Bordetella bronchiseptica*, *Pasteurella multocida*, porcine epidemic diarrhea virus (PEDV) at 6 months of age, vaccinating against *E. coli* and *C. perfringens* 5 and 2 weeks pre-farrowing, and boosted against PEDV 1–3 weeks prior to farrowing. Sows are vaccinated against *Bordetella bronchiseptica*, *Pasteurella multocida*, and *Erysipelothrix rhusiopathiae* 5 and 3 weeks pre-farrowing, boosted against PEDV 1-3 weeks prior to farrowing, boosted against PPV, erysipelas, and 6 strains of leptospirosis at weaning, and boosted against *E. coli* and *C. perfringens* at 3 weeks pre-farrowing.

Piglets of approximately equal weights and similar genotype were cross-fostered onto each female between days 5 and 7 of lactation to establish an initial litter size of 10. A new set of approximately 1-week-old piglets was cross-fostered onto each female at the end of the initial three-week period and at every subsequent 3 weeks. Litter size of replacement litters was dependent on the number of piglets each female had supported up to weaning of the previous litter. If piglet weight gain dropped below 0.5 kg/piglet/week, that piglet was removed from the trial. A female was removed from the study when only six piglets remained in her litter. No creep feed was provided during the suckling period.
Sows were weighed, feed intakes measured, and milk samples collected weekly. The diet used was formulated to meet the requirements for lactating sows proposed by NRC (1998). The lactation diet consisted of 67.47% ground corn, 24.08% soybean meal, 5% fat, 0.89% limestone, 1.86% Dical-PO4, 0.35% trace mineral salts, 0.2% vitamin mix, 0.2% UI sow pac (Biotin 100mg/lb, Choline 300,000 mg/lb, Folic Acid 1,000 mg/lb), and 0.05% L-lysine HCL, all on a per U.S. ton (2,000 lbs) basis. Sows were fed twice per day to appetite with feed refusals being collected once per day to calculate feed intake. Milk was collected, once per week, after intravenous injection of l mL of oxytocin (20 U.S.P. units per mL) in an ear vein to induce milk letdown. Hand milking was used to collect approximately 50 mL of milk. Milk was analyzed for protein and fat concentrations at Dairy Lab Services, Inc., Dubuque, Iowa. Piglet weights were recorded weekly to calculate litter gain.

2.2. Statistical analysis

The insufficient sample size of the study after 8 weeks of lactation precluded analysis of statistical significance beyond that point. Data from the initial 8 weeks of study were analyzed by one-way analysis of variance using breed as the main effect and week of lactation, female weight, feed intake, litter weight gain, 3-week total litter weight gain, milk protein concentration, and milk fat concentration as dependent variables (StatView SE+Graphics^{TM}, v 5.0, copyright 2001, Abacus Concepts, Inc., SAS). Linear and polynomial regression equations with r^2 coefficients were also calculated (CA-Cricket Graph III Version 1.01, copyright Computer Associates International, Inc., 1992).

2.3. Ethics approval of research

The studies were conducted under an approved protocol by the University of Illinois Institutional Animal Care and Use Committee (IACUC Protocol # A0R185/2313).

3. Results and discussion

3.1. Female performance

Average lactation length and number of piglets nursed/week was 7.17 weeks and 9.62 piglets, 10.4 weeks and 9.26 piglets, and 9.67 weeks and 9.22 piglets for M, M/Y, and Y sows, respectively. Average female body weight and average weekly feed intake (FI) for the first 8 weeks of lactation are presented in Figure l. Meishan sows weighed significantly less and had lower FI ($P < 0.05$) than M/Y and Y sows, which were similar for these traits (Figures 2 and 3, respectively). In comparing sows from Meishan and Western breeds, Meishan and Meishan crossbreeds have been shown to be lighter and have lower feed intake during lactation compared with Western breeds [19,20]. In the current study, the M/Y crossbreed sows were more comparable in FI and weight to the Y than to the M sows.

Over the 8-week lactation period, the average female body weight of all genotypes (Figure l) tended ($P > 0.05$) to gradually decrease from an average high weight of 155.2 kg at week 1 to an average low of 141.94 kg at week 7, after which female body weight trended to increase. There are few recent studies that examine lactation periods beyond week 5, with commercial farms now using the practice of weaning piglets at 3–4 weeks of age or younger. Female weight normally declines over the lactation period even when feeding high levels of energy during lactation. The differences in energy intake, whether during gestation or lactation, only affect the amount of weight loss, since there is normally a decrease in body weight during lactation [26,27]. The results from the present study agree with Elsley et al. [27] in that the rate of weight loss decreased as the 8-week lactation progressed.

The average FI of all genotypes (Figure l) showed an increasing trend ($P > 0.05$) over the first 6 weeks, from an average of 29.32 to 37.04 kg. This was followed by a slow decrease in FI over the remaining lactation period, although there was wide variation between sows. Feed intake has been shown to increase as lactation progresses [28], with differences in energy concentration in the diet affecting how much feed was consumed.

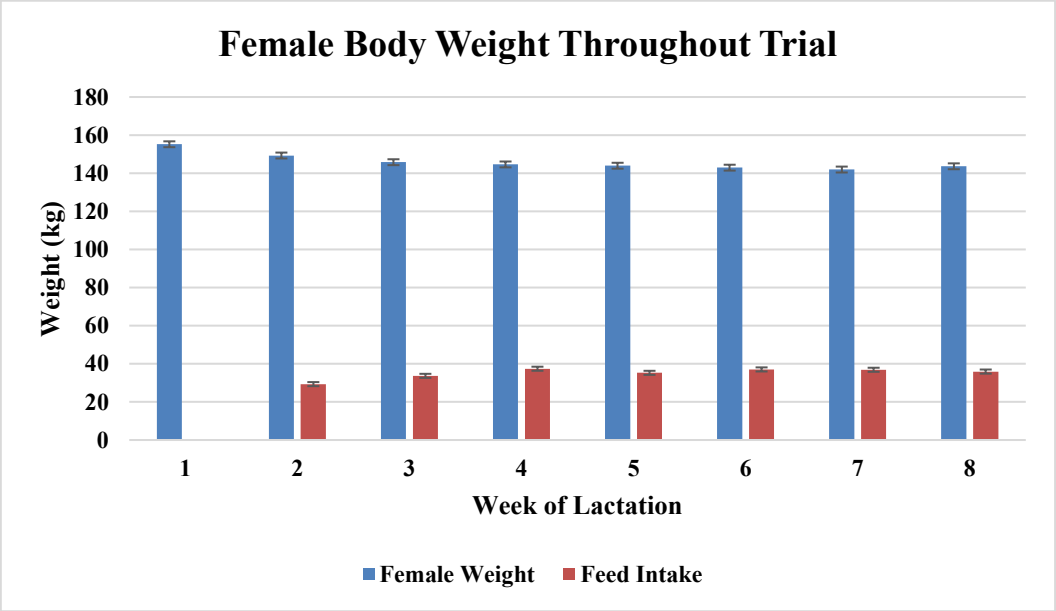


Figure 1. Overall female body weight and feed intake over the extended lactation trial.

Significant differences ($P < 0.05$) in average female body weight were observed (Figure 2) between M vs. M/Y and Y throughout the first 8 weeks of lactation. Even with the large differences in body weight, relative weight change was similar among the M, M/Y, and Y sows for the initial 8 weeks on the trial (Figure 2). Weight loss occurs during lactation in Western breeds, Meishan, and crossbred sows [19,22,29]. Results from the present experiment (Figure 2) showed that weight loss stabilized at 8 weeks, and sows eventually gained weight as lactation progressed. Elsley et al. [27] has shown that with lactations extending to 8 weeks, the rate of weight loss decreased and weight eventually increased in Large White sows.

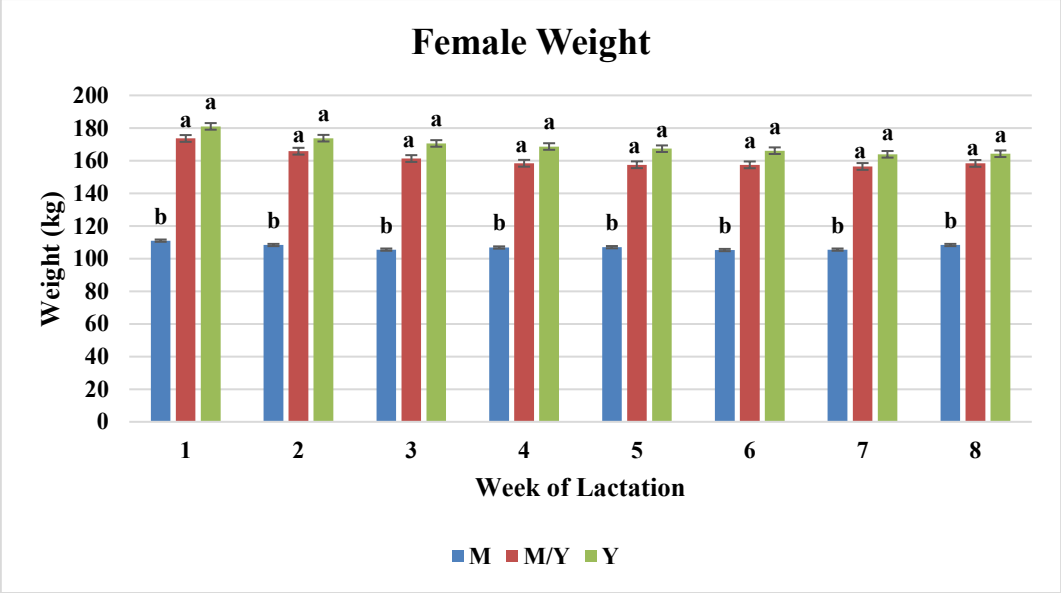


Figure 2. Female body weight between each genotype over extended lactation trial. Statistical analysis from the initial 8 weeks of study only. Means with different superscripts differ among genotypes ($^{a,b}P < 0.05$) within the week of lactation.

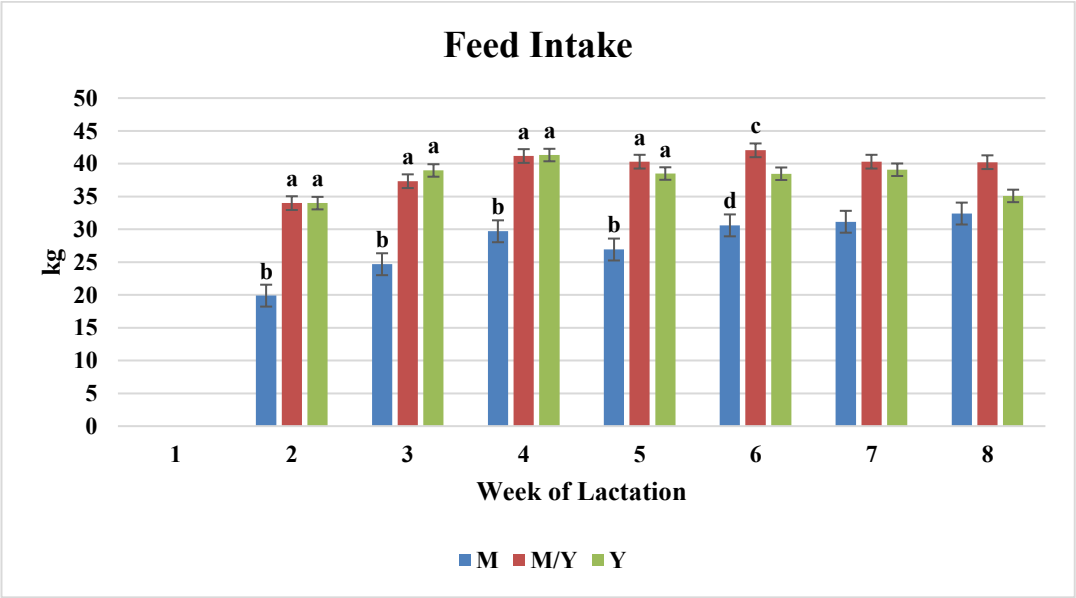
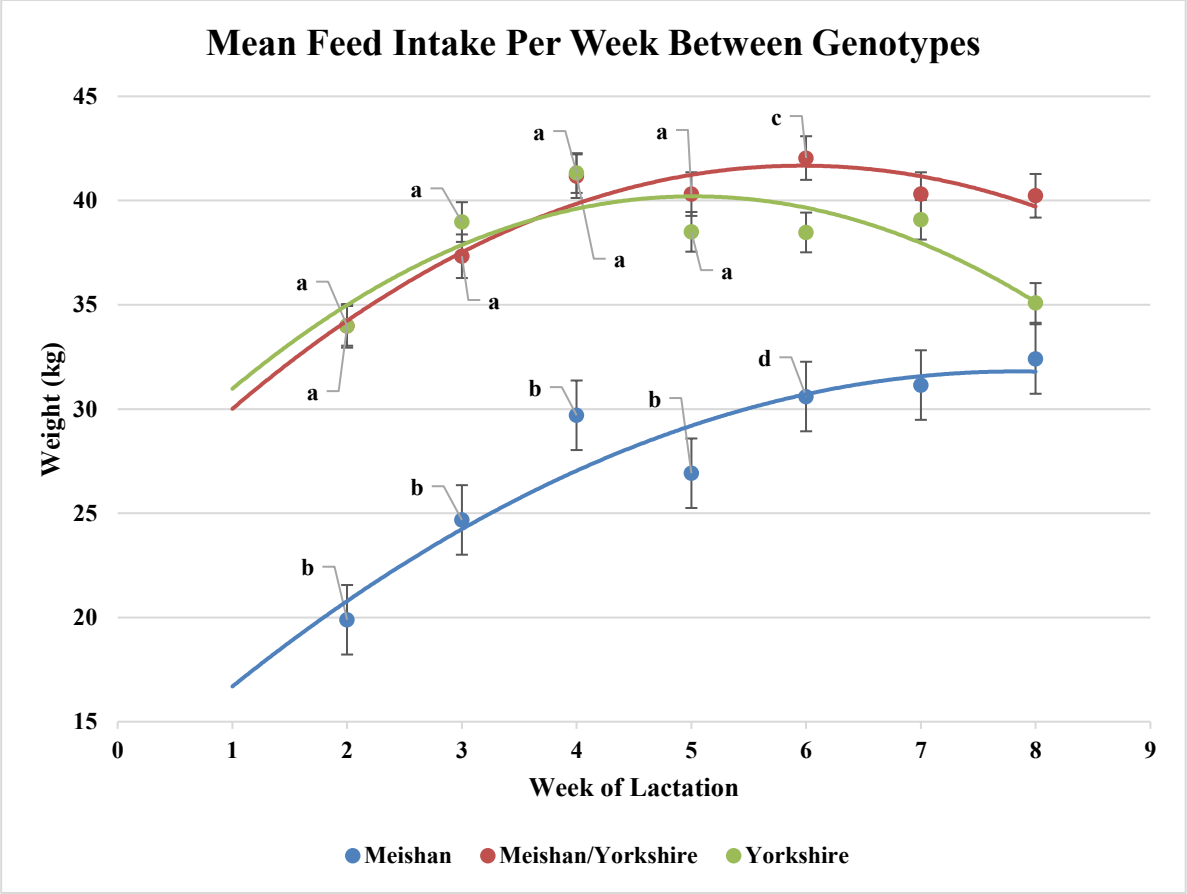


Figure 3. Female feed intake between each genotype over the extended lactation trial. Statistical analysis from the initial 8 weeks of study only. Means with different superscripts differ among genotypes ($^{a,b}P < 0.05$; $^{c,d}P < 0.01$) within the week of lactation.

Meishan sows had lower FI ($P < 0.01$) than M/Y and Y sows for weeks 2–5 and were lower than M/Y sows ($P < 0.05$) for week 6 (Figure 3). Feed intake of M/Y and Y sows was similar until week 5. Feed intake for M/Y and Y sows declined after week 5, though Y had a more rapid decrease in FI. Meishan sows were still experiencing an increase in FI from weeks 4 to 8, while FI for M/Y and Y continued declining. Feed intake of Meishan and crossbreds has been shown to be lower than for sows of Western breeds over lactation [19,20,22]. This agrees with the results for the M

sows in the present study but not for the M/Y sows, where the M/Y sows consumed more feed than Y of comparable size (Figure 4). Feed intake has also been shown to increase over the lactation period [26,27], which agrees with the M results. However, the M/Y and Y sows in this study showed an increased FI during the first 5 weeks of lactation, followed by a slight decline as lactation progressed. These results could be due to the M/Y and Y sows' body weight returning to normal, resulting in not as much feed being needed for maintenance, lactation, and replenishing weight loss. Decreasing milk yield in late lactation would also affect feed intake. These results could be due to decreased demand on the female as litter size decreased and their bodies adjusted to the extended lactation demands. Meishan sows followed this trend, although there were significant differences in weight due to their smaller body size compared to the M/Y and Y sows.



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Week Number	2	3	4	5	6	7	8
M (n=)	6	5	5	5	4	4	3
M/Y (n=)	10	10	10	10	9	9	9
Y (n=)	9	9	9	9	9	9	8

Figure 4. Average feed intake (kg) ± SEM between sows plotted against week of lactation for Meishan, Meishan/Yorkshire, and Yorkshire sows. Statistical analysis from the initial 8 weeks of study only. Means with different superscripts at each timepoint differ among genotypes ($^{a,b}P < 0.05$; $^{c,d}P < 0.01$). M, M/Y, and Y = number of sows per week.

3.2. Litter performance

Litters were standardized to 10 piglets at the start of the study. Average litter size was not different ($P > 0.05$) among the genotypes over the first 8 weeks of the lactation period (Figure 5). Previous studies showed that the Meishan sows produce larger litters than Western breeds at birth and at weaning [19,20,30]. Further, F1 crosses of Meishan and lines selected for improved maternal traits produce litters as large or larger than purebred Meishan, with birth and weaning weights comparable to Western breed piglets while consuming less feed [19].

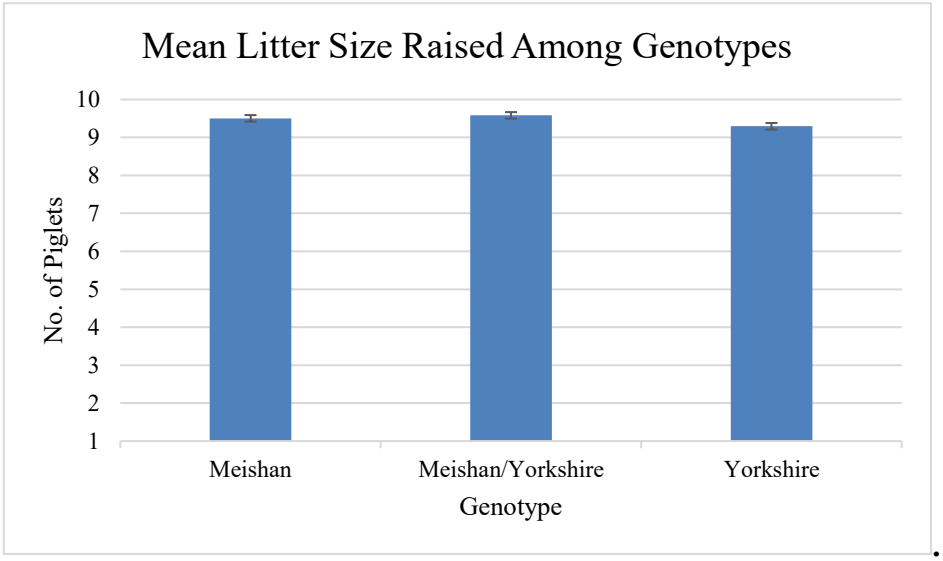


Figure 5. Mean litter size raised among the genotypes for the first 8 weeks of the lactation period.

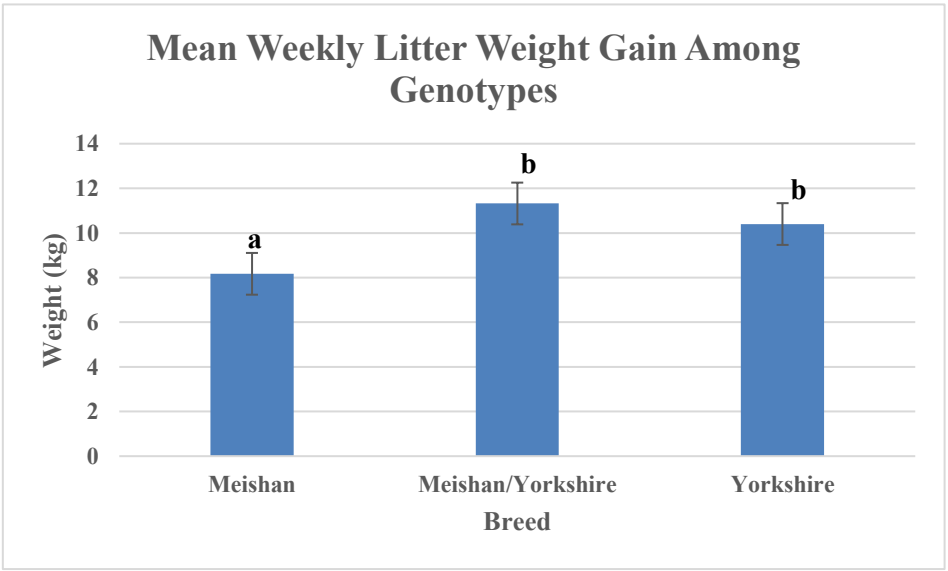


Figure 6. Average litter weight gain (kg) ± SEM for Meishan Meishan/Yorkshire and Yorkshire sows for the first 8 weeks of the study. Means with different superscripts differ ($^{a,b}p < 0.001$).

There were significant differences ($P < 0.05$) among the genotypes in total litter weight gains per week (Figure 6), with litters of M sows having lower weight gains than the other two genotypes. McLaren [19] reviewed data from France showing that Meishan/Large White or Meishan/French Landrace sows produced heavier weaning weights than the purebred Large White, French Landrace, or Meishan pigs. In contrast, van der Steen and de Groot [20] found small differences between Dutch Landrace and Meishan sows for litter weight gains when sows were suckling piglets of the same genotypes.

Average litter size decreased linearly during the first 8 weeks of lactation as piglets were removed because of reduced milk production by the female (Figure 7). This is not surprising; by 6 weeks, the sow's lactation has peaked and begun to decline. Average litter size declined in all three genotypes by week 6 with significant differences ($P < 0.05$) between Y vs. M and M/Y at weeks 3 and 4, and between both M and Y vs. M/Y at week 5. The change in litter size was different for each genotype, especially for the M/Y sows.

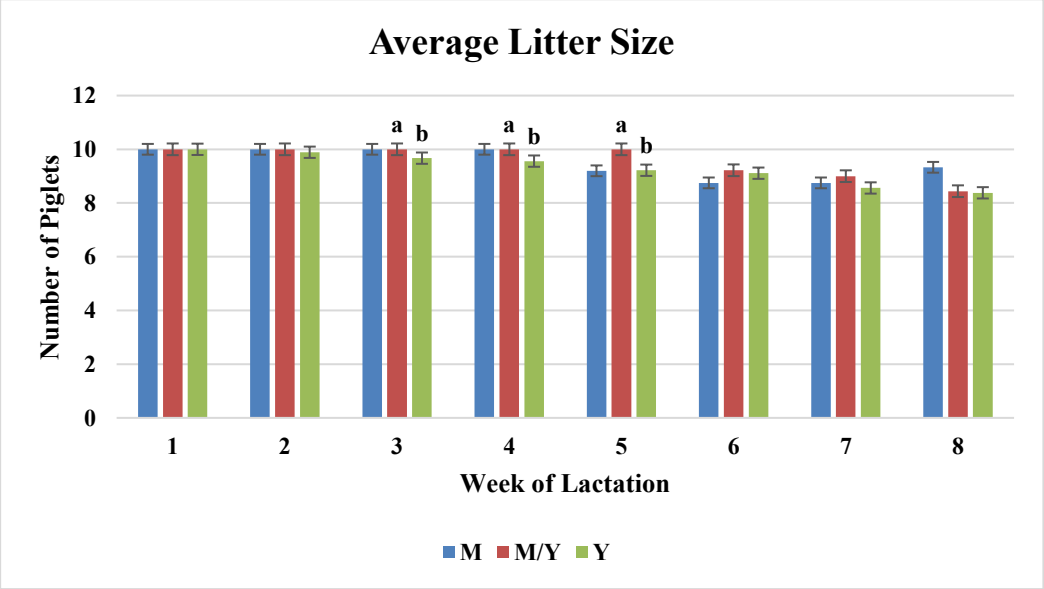


Figure 7. Litter size for each genotype over the extended lactation trial. Means with different superscripts differ among genotypes ($^{a,b}P < 0.05$).

Average litter weight gain (Figure 8) decreased over the lactation period for all genotypes, with significant differences ($P < 0.05$) between M/Y and Y vs. M sows at 2–5 weeks. The litter weight change was essentially the same for M/Y and Y sows over the entire trial. Litters from Meishan sows had changes similar to litters of M/Y and Y sows until week 7, after which litter weight started increasing and equaled Y litter weights at week 8 (Figure 8). Average 3-week litter weight gains (Figure 9) were significantly greater ($P < 0.05$) for litters of M/Y and Y sows vs. M sows after 3 weeks (lactation period 1, 1–3 weeks) and 6 weeks (lactation period 2, 4–6 weeks) but did not differ for the subsequent weeks (lactation period 3, 7–9 weeks). Meishan sows had lower litter weight gains until week 8 compared with the other genotypes, after which there were no differences in litter weight gains between the genotypes.

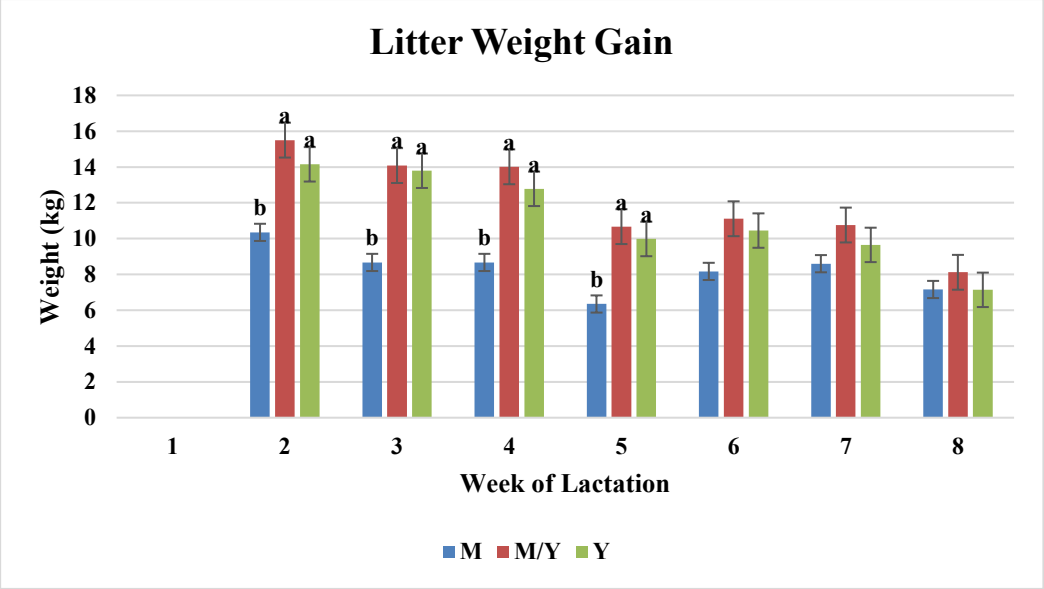


Figure 8. Litter weight gain for each genotype over the extended lactation trial. Means with different superscripts differ among genotypes ($^{a,b}P < 0.05$).

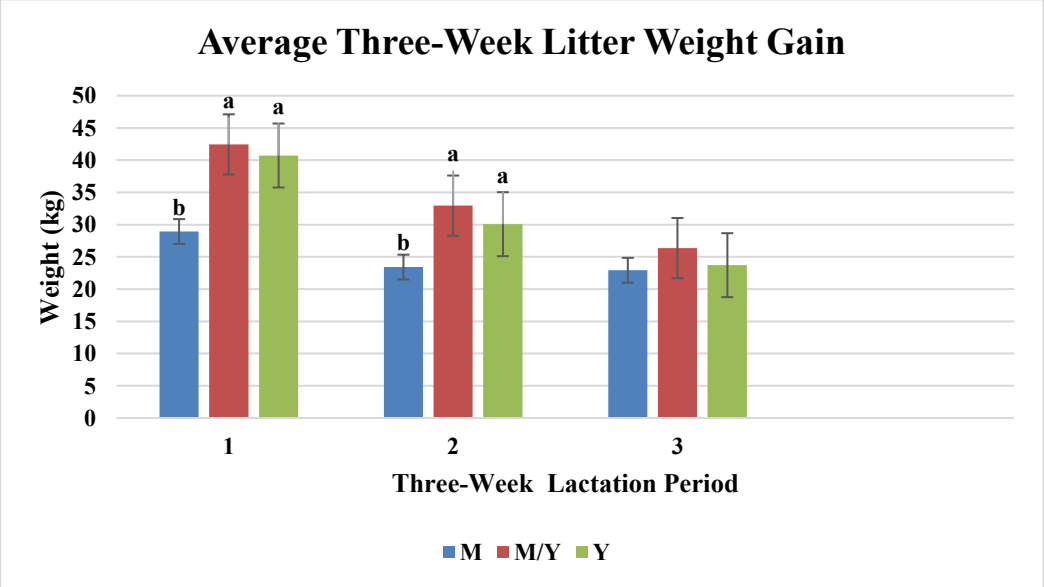


Figure 9. Average 3-week litter weight gains over the extended lactation trial. Period 1 (1–3 weeks), period 2 (4–6 weeks), and period 3 (7–9 weeks). Means with different superscripts differ among genotypes ($^{a,b}P < 0.05$).

Litter weight gain per week showed a trend to decrease linearly over the 8-week period as litter sizes and milk produced decreased. There is little information available on litter size change when new litters are fostered onto sows over an extended lactation. One or two piglets may die before weaning over a 6–8-week lactation with a female rearing only one litter. Pre-weaning mortalities of 10%–15% are common [31,32]. It has been suggested that sows can be used as foster sows by weaning her own largest piglets at 3 weeks and then fostering a new set of smaller

piglets—fewer in number and with lower total weight than those removed—to suckle for another 2 weeks without detrimental effects [25]. The result would be an increased overall piglet production. Chinese Meishan pigs have been studied due to their large litter sizes and superior maternal characteristics. New litters of poor-quality piglets have been cross-fostered at specific intervals after rearing their own litters. English et al. [25] used Chinese Meishan pigs to cross-foster 3-week-old underdeveloped piglets to suckle for another 2 weeks before being weaned. They showed a successive litter size decrease. The sows were able to sustain the litter over an extended lactation period of 20–22 weeks. Results from the present study followed a similar pattern in that litter size decreased as lactation progressed. Due to the overall decrease in litter size, litter gain would also tend to decrease, although piglets continued growing over the lactation period. The three-week weight gain also followed this trend.

Meishan and Meishan-Yorkshire crossbred sows have been shown to have larger litters and larger litter weights than domestic sows [19,21,22]. However, in those studies, if litter sizes were equalized, Meishan and Meishan crossbred sows would have smaller weight piglets than domestic sows. Van der Steen and de Groot [20] showed small differences in piglet weights between Dutch Landrace and Meishan female suckling piglets of the same litter size and genotype. In the present study, Meishan female litter weights were significantly lower than M/Y and Y during the first 6 weeks of lactation. No differences were then found during the rest of lactation. Many factors influence milk production in sows, including nutrition, non-nutritional factors, and environmental factors, including female and pig characteristics; for instance, first-parity sows produce less milk than older sows [9]. The body condition of the sows, the number of functional teats, litter size, weight of the piglets, ambient temperature, and photoperiod have all been shown to affect lactation [9,11,16]. In the present study, the differences were probably due to lower milk production in M sows, since litter size, piglet weight, nutrition, and environmental conditions were comparable among all sows. Various factors, including litter size, birth weight, parity, genotype, endocrine status, stress levels before, during, and after farrowing, and nutrition, play a role in influencing colostrum and milk yield [4,6,8,9,11,16,33]. The 3-week litter weight gain results showed the same trend of decreased weight gain. There was also a significant improvement in 3-week litter weight gain for M/Y and Y sows over the M sows until around the 10th week of lactation.

3.3. Milk composition

The percentages of protein and fat in milk were evaluated over the extended lactation period for all sows (Figure 10). Average milk protein concentration of all genotypes decreased over the first 2 weeks of lactation; then, it increased almost linearly over the rest of lactation. These changes may be due to the solids not being diluted in the liquid portion of the milk as milk volume decreases over the lactation period, especially after the peak of lactation at around 3 weeks [34]. The fat percentage of all genotypes decreased at 8 weeks of lactation, with wide variation. Breed differences may contribute to the variation. Further, we realize that the administration of oxytocin to stimulate milk letdown may decrease the fat percentage and increase the water content of the milk [35,36]. Administering oxytocin once per week has no permanent effect on the baseline nutritional composition of mature sow milk [37]. Because oxytocin clears from a sow's bloodstream within minutes, any minor compositional changes are strictly temporary and resolve within hours [37]. Therefore, if there is an effect of oxytocin on milk composition, it is that the values presented are a slight underestimation of the actual milk composition. Milk protein and fat concentrations have been shown to follow similar trends in most studies, as is the case in the present

trial. Several studies [7,38,39] have reported protein decreasing in weeks 1 and 2 and then increasing out to at least 8 weeks, while fat decreases over the lactation period until 8 weeks.

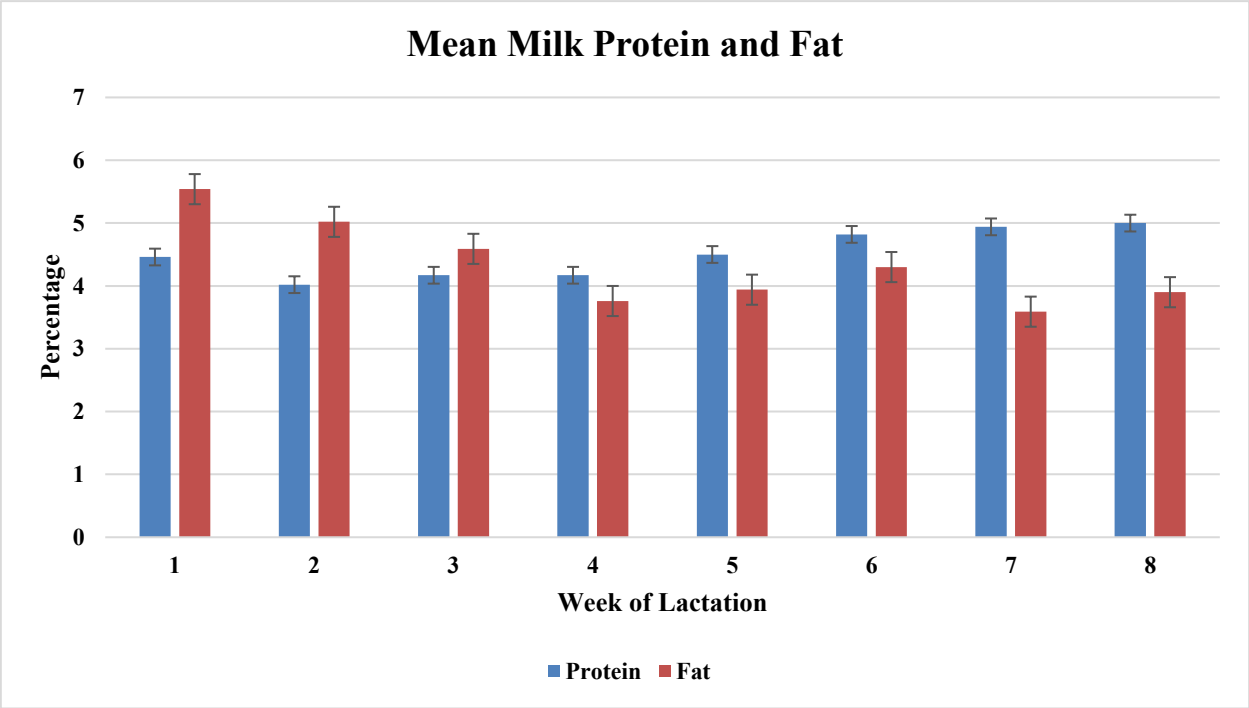
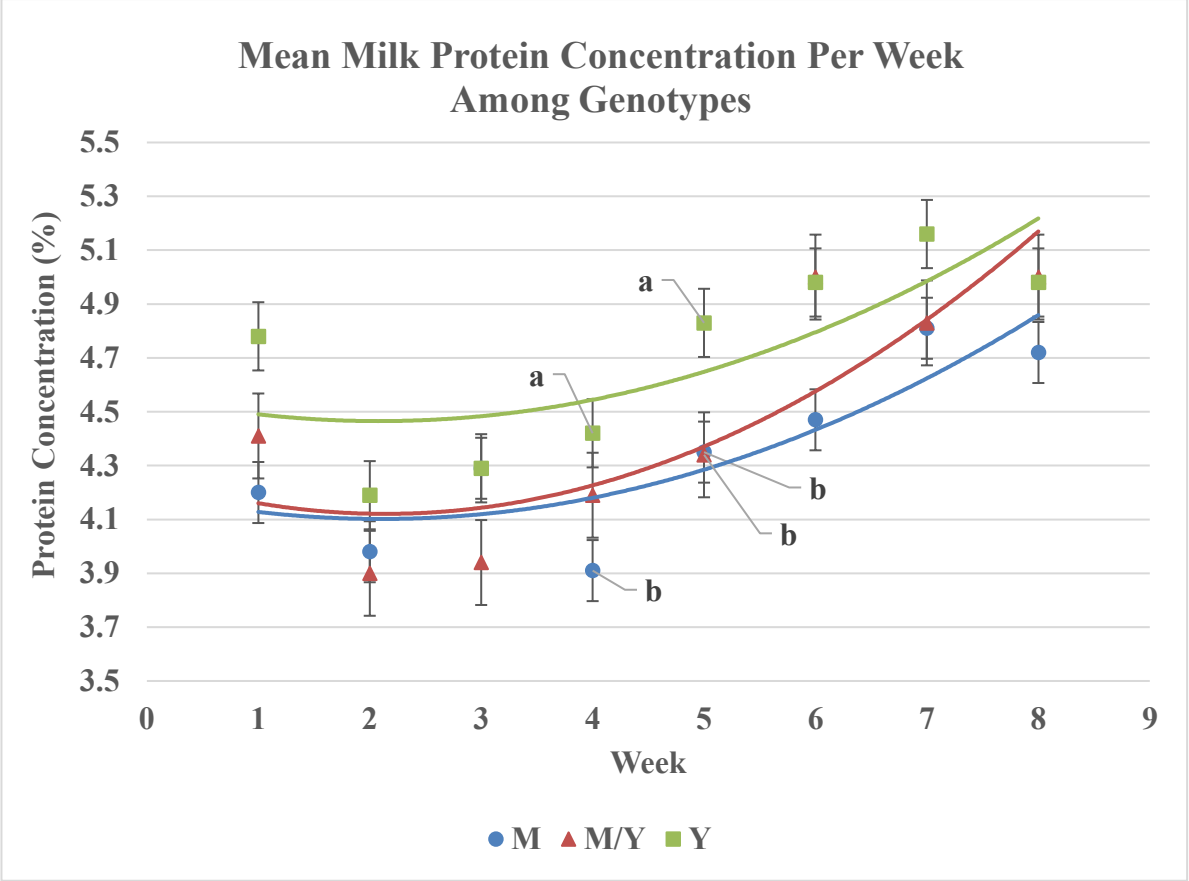


Figure 10. Mean milk protein and fat for all sows over the extended lactation trial. The regression curve ($y = 0.029x^2 - 0.131x + 4.370$, $r^2 = 0.820$) for protein percentage among the three genotypes showed a decrease over the first 2–3 weeks of lactation, followed by an increasing trend, with significant differences ($P < 0.05$) between Y and M at 4 weeks, and between Y vs. M/Y and M at 5 weeks (Figure 11).

The change in protein concentration was similar among all genotypes, showing both an initial decrease and then an increase in protein concentrations (Figure 11). The Y sows tended to have the highest protein concentrations (ranging from 3.78% to 7.30%) and the Meishan sows the lowest (ranging from 3.36% to 5.62%), with the M/Y sows presenting intermediate values (ranging from 3.39% to 6.38%) when analyzed over the entire trial. When mean protein concentration over the duration of the trial was calculated, it showed an overall significant difference ($P < 0.05$) in M vs. Y and M/Y sows, even though significant differences were not found for each weekly value. Few studies have compared milk composition of M, Y, and M/Y sows; Zou et al. [40] found Meishan milk to be lower in protein concentration at days 7 and 21 of lactation than Yorkshire milk. These results are comparable to results in the present study. Few significant differences over the lactation period were shown in the present trial, but milk protein concentration of M/Y was intermediate between Y and M protein concentrations. All genotypes showed a trend of decreased protein concentration for the first 1–2 weeks, then increasing the remaining period of lactation.



M	(n=)	4	3	5	4	5	3	4	2
M/Y	(n=)	9	8	7	9	8	7	5	5
Y	(n=)	8	9	9	9	9	9	7	6

Figure 11. Average milk protein concentration (%) ± SEM plotted against week of lactation for Meishan, Meishan/Yorkshire, and Yorkshire sows. Statistical analysis from the initial 8 weeks of study only. Means with different superscripts at each timepoint differ among genotypes ($^{a,b}P < 0.05$). M, M/Y, and Y = number of sows per week.

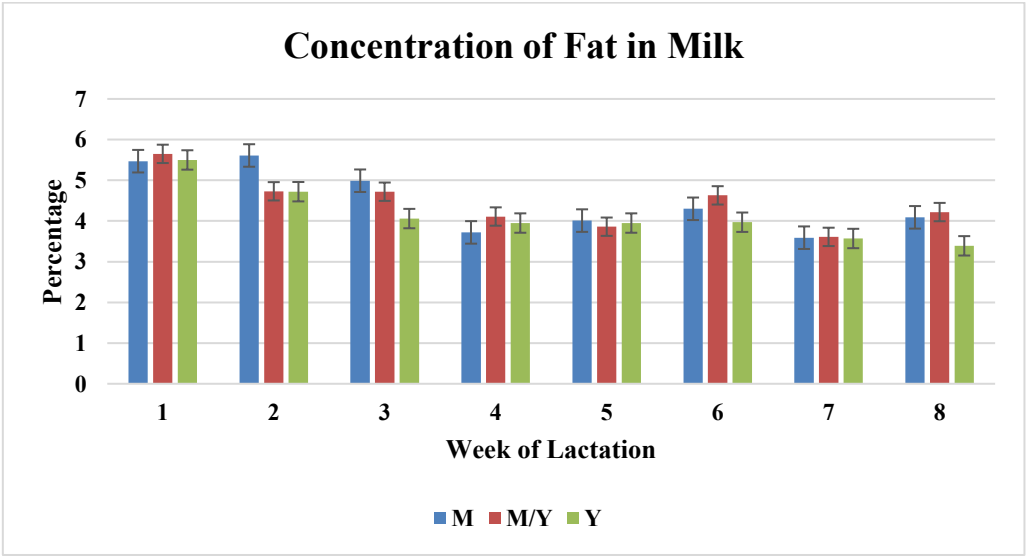
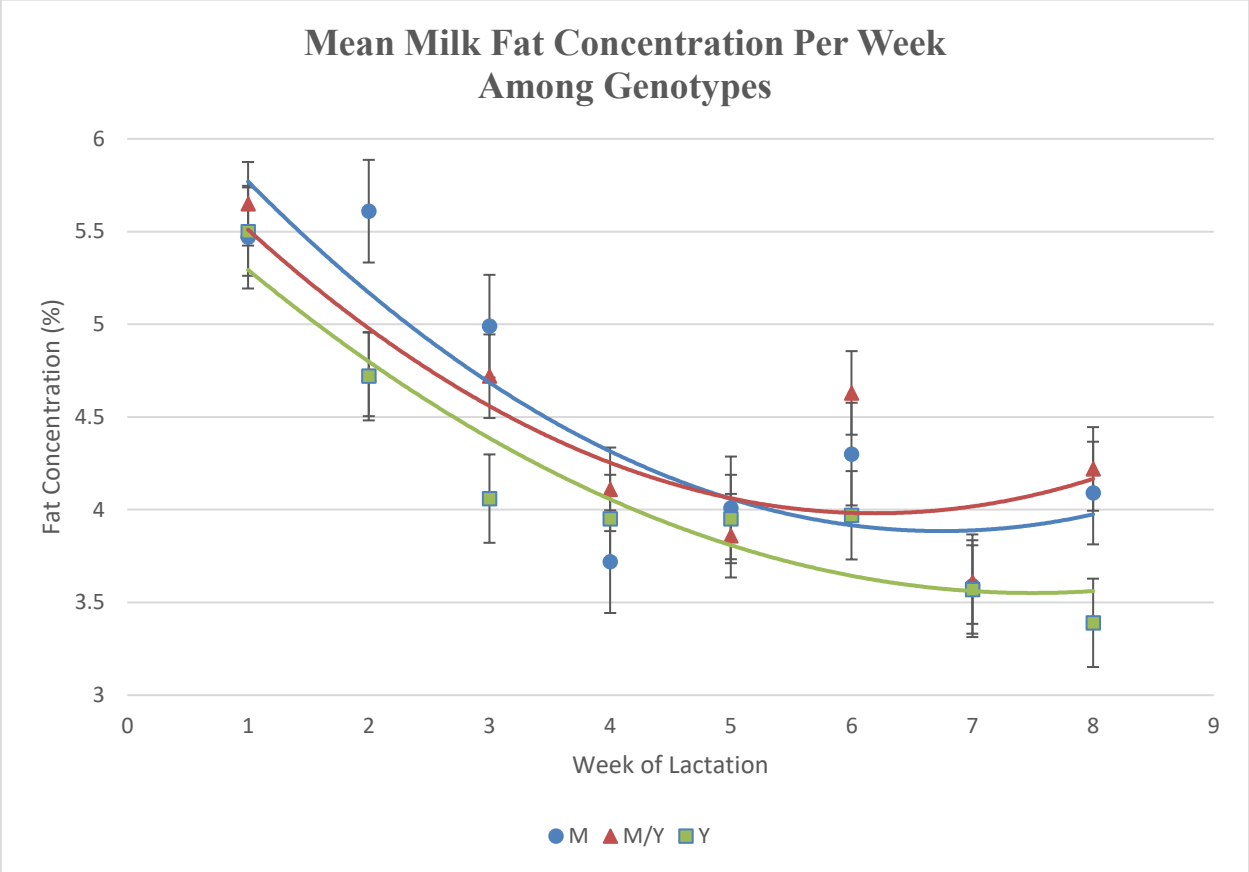


Figure 12. Milk fat concentration for each breed over the extended lactation trial.

Fat percentage tended to decrease over the course of lactation, with the rate of change decreasing as lactation progressed. The lowest individual fat percentage was 2.31%, and the highest was 9.69%. No difference in milk fat percentage (Figure 12) was observed among the genotypes over the entire observation. Fat concentration was previously shown to be significantly higher in M and Y sows [40]. Results from the present study also followed the trend of a previous study [40], with M and M/Y having a higher fat percentage than Y. However, M and M/Y fat concentrations varied among individual sows, with M/Y milk usually having similar or higher concentration of fat compared to M. No significant differences were found among any of the three genotypes, and the regression curve ($y = 0.057x2 – 0.197x + 6.215$, $r2 = 0.858$) showed a decreasing trend during the first 8 weeks of the trial (Figure 13).



M	(n=)	4	3	5	4	5	3	4	2
M/Y	(n=)	9	8	7	9	8	7	5	5
Y	(n =)	8	9	9	9	9	9	7	6

Figure 13. Average milk fat concentration (%) ± SEM plotted against week of lactation for Meishan, Meishan/Yorkshire, and Yorkshire sows. Statistical analysis from the initial 8 weeks of study only. No significant differences were found among genotypes. M, M/Y, and Y = number of sows per week.

Conclusions

When using sows for extended lactation, these results showed that Yorkshire and Meishan/Yorkshire sows would produce higher litter weight gain/week and have longer lactation length than the Meishan sows. While we only used younger (≤1 parity) sows in this study, the use of

higher-parity sows may also allow for longer lactation length and higher litter weights. Future research will be required in this area to determine if Meishan sows would be useful in nurse female production schemes. In addition to the usefulness of Meishan for nurse sows, more research is needed to identify optimal nurse female schemes using Western breeds.

Author contributions

Conceptualization, D.L.R., G.T.B. and M.B.W.; methodology, M.B.W, G.T.B., W.L.H., M.E.; validation, M.B.W and DLR.; formal analysis, D.L.R., E.A.B. and G.T.B.; investigation, D.L.R. and G.T.B.; resources, M.B.W.; data curation, M.B.W.; writing—original draft preparation, D.L.R.; writing—review and editing, M.B.W, W.L.H., G.T.B. M.E., E.A.B.; supervision, M.B.W.; project administration, M.B.W.; funding acquisition, M.B.W. All authors have read and agreed to the published version of the manuscript.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Data availability statement

Summarized data is available upon request from Dr. M.B. Wheeler (mbwheele@illinois.edu).

Conflict of interest

The authors have no conflicts of interest.

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