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Short communication

A comparison of the composition of milks from Meishan and crossbred pigs

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Abstract

Because of low energy reserves at birth, piglets are dependent on the sow's milk for survival. Breed differences can influence milk composition. The objective of this study was to examine litter characteristics, milk composition including calcium and the water holding capacity of casein, solvation, between the highly prolific Meishan breed and lean crossbred pigs. Samples were collected by hand-milking at early (days 3–5) and late (days 20–21) lactation. Milk fat percentage for Meishans was higher than for the crossbred, especially during early lactation ($10.72\pm0.5 > 8.91\pm0.4$ (crossbred); $P<0.0005$). During late lactation, Meishans had $8.60\pm0.49 > 6.49\pm0.39$ (crossbred); $P>0.05$. No differences were observed between breeds for lactose or protein at either sampling time. Calcium concentration (mg/dl) was higher in Meishan milk than in crossbred milk at early lactation ($0.204\pm0.01 > 0.178\pm0.01$; $P<0.05$). There were no differences at late lactation. Crossbred solvation values (g water/g protein) were the same (2.18 ± 0.12) as Meishan (2.36 ± 0.16). Those values were also similar at late lactation. The mean litter size for the Meishans was higher than that of the crossbred ($13.8\pm0.1 > 11.1\pm0.7$; $P<0.05$). Mean birth weights (kg) were less for Meishans ($0.91\pm0.09 < 1.4\pm0.07$; $P<0.05$) and similarly, weaning weights ($4.78\pm0.41 < 5.94\pm0.31$; $P<0.05$). Milk from Meishans might provide an early advantage to improve survivability of piglets by supplying more fat and higher calcium for bone development than traditional breeds.

Keywords: Milk composition; Meishan; Pig; Solvation

1. Introduction

Upon examination of the milks of over 200 species of mammals, Jenness (1974, 1988) observed considerable variation in their overall composition, including protein, fat and lactose. For example, the milks of the primates, including man, are relatively devoid of casein (0.1–0.2%), whereas those of pigs (sow milk) contain ~4%. Additionally, he observed breed variations in milk composition among Bos taurus, the Jersey breed being highest in the percentage of fat. In a joint study, Thompson et al. (1969) and Jenness observed a direct relationship between casein pellet solvation (g water/g protein) and the heat-stability of bovine milk, an observation which appeared to involve, in part, the total con-

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centration of ionised calcium in the system. As the calcium ion concentration increased, solvation decreased and vice versa. Thompson and Farrell (1974) confirmed this observation by reporting that the calcium-binding property of casein relates to the overall stability of micellar casein.

Despite evidence that breed differences in pigs significantly influence milk production and composition (Fahmey, 1972), few studies have been conducted (over the course of lactation) which included Meishan pigs. These pigs are a highly successful breed from China, which are characterized by high back-fat. Despite higher body lipids, their piglets tend to weigh less than traditional breeds at birth, and are more resistant to cold and starvation (Le Dividich et al., 1991). Although the colostrum appears similar in composition to conventional breeds (Herpin et al., 1993), the purpose of this study was to characterize properties of mature milk of the Meishan and crossbred pigs.

2. Materials and methods

2.1. Animals

Crossbred ($n = 9$) and Meishan gilts ($n = 5$) were reared at Swine Unit II, North Carolina State University. Crossbred pigs consisted of 1/4 Landrace, 1/4 Large White, 1/4 Duroc and 1/4 Hampshire. Pigs were hand-milked after i.m. injection of 0.5 to 1.0 ml (20 U/ml) oxytocin. Samples were taken at early (day 3) and late (days 20 to 21) lactation. All sows were maintained on a standard diet based on NRC (1988) requirements (Table 1) and fed ad libitum. Litters of the Meishan and crossbred sows were weighed at birth and at each sampling period.

Approximately 30 ml of milk were collected from each sow studied. The milk was collected and pooled from the first three pairs of teats for each sow at each sampling time, pooled, and then placed on ice. Aliquots of well-mixed milk were taken for fat and four samples from each breed were chosen at random for fatty acid analysis. The remainder of all samples was centrifuged to remove fat and the skim milk was assayed in duplicates for lactose, total protein, calcium and solvation.

Table 1
Percentage composition of sow diets[a]

Ingredient	Percentage
Wheat MIDDS	7.5
Maize	60.73
Soybean meal	18.40
Limestone	1.45
Molasses phosphate	3.31
Monophosphate	1.49
Salt	0.80
Fat	3.50
Maize gluten feed	2.50
Trace mineral/vitamin[b]	0.06
Calcium	0.92
Total phosphorus	0.70
Crude protein	15.83
Metabolizable energy (MJ/kg)	13.80

[a] Southern States, Durham, NC, USA.

[b] Choline chloride (0.105), folic acid (0.034), biotin (0.05), vitamin A (5156 IU), swine vitamin P (0.10), vitamin E (12.4 IU), L-lysine-HCl (0.05), sodium selenite (0.05), magnesium oxide (0.075), iron sulfate (0.025).

2.2. Proximate analysis

Fat percentage was determined by the Babcock method (AOAC, 1984). Total skim-milk protein was measured using the bicinchoninic acid assay (BCA) following the procedures as suggested by the manufacturer (Pierce Chemicals, Rockford, IL). Lactose was measured using a YSI Glucose Analyzer with a lactose membrane (Yellow Springs, OH).

For analysis of fatty acids, milk lipid was extracted according to the method of Folch et al. (1957) as modified by Iverson (1988). Fatty acid methyl esters were prepared directly from the pure extracted lipid (filtered and dried over anhydrous sodium sulfate), using 1.5 ml 8% boron trifluoride in methanol (v/v) and 1.5 ml hexane, capped under nitrogen, and heated at 100°C for 1 h. Fatty acid methyl esters were extracted into hexane, concentrated, and brought up to volume (50 mg/ml) with high purity hexane.

Duplicate analyses of fatty acid methyl esters were performed on samples using temperature-programmed gas liquid chromatography according to Iverson (1988) and Iverson et al. (1992), on a Perkin Elmer Autosystem II Capillary FID gas chromatograph fitted with a 30 m × 0.25 mm i.d. column coated with 50% cyanopropyl polysiloxane (0.25 μm film thickness J&W DB-23; Folsom, CA) and linked to a computerized integration system. Fatty acids were identified and quantified according to Iverson et al. (1997) using a combination of standard mixtures (Nu Check Prep) and silver nitrate chromatography, as well as an ion-trap mass detector. Fatty acids are expressed as weight percent of total fatty acids.

To determine calcium concentration, milk was diluted 1:1000 using 5% lanthanum oxide buffer (pH 1.7) and measured by absorption spectrophotometry.

Casein pellet solvation (g water/g protein) was essentially performed as described by the method of Thompson et al. (1969) except that a Beckman Model L8M ultracentrifuge was used with automatic temperature control. Four ml of whole milk were pipetted into 4 ml cellulose nitrate centrifuge tubes and centrifuged at $68{,}000 \times g$, 25,000 rev./min, in an SW-39 rotor for 35 min at 37°C. Following centrifugation, the tubes were drained for 5 min and the tube cut off 2 to 3 mm above the pellet. The tube plus the pellet were weighed (W_1), frozen at −40°C, and lyophilized overnight. The dry pellet and tube were weighed (W_2) and the pellet alone was weighed, being careful to scrape away all the pellet in the tube (W_3). Solvation was determined by the equation: $W_1 - W_2/W_3 =$ g water/g protein.

2.3. Statistical analysis

A general linear-models procedure was performed on the data contrasting the breeds and lactation stage for the above-mentioned variables. A one-way analysis of the variance was performed for the two stages of lactation between the two breeds (t-test). Because the sample size was small, <15, a Wilcoxon rank-sum test was performed (because of the absence of a normal distribution and as determined by small sample size). In addition, the correlation coefficient was determined for the above-mentioned milk properties. Fatty acid statistical analysis was done, using a two-way analysis of the variance. A paired t-test was done for early- vs. late-lactation samples.

Comparison means and standard deviations were chartered for Meishan and crossbred breeds at early- and late-lactation for: piglets born alive or dead, collective birth and post-weaning weights. The statistical model included stage of lactation and breed for fat, protein, lactose, calcium, and solvation.

3. Results

3.1. Proximate analysis

Total protein, lactose and milk fat contents are summarized in Table 2.

3.2. Solvation and calcium

Solvation values from Meishans were slightly higher than the crossbreds at early-lactation and at late-lactation. At early-lactation, milk from the crossbreds had less calcium than the Meishans ($P<0.05$). At the same time, crossbred milk calcium concentrations increased ($P<0.01$) by late-lactation with only a slight increase observed in the Meishans. There were positive correlations among values for solvation values, proteins, and calcium to the breed. Over time, the slight decreases observed in protein content were reflected by the solvation values and inversely reflected in the calcium concentration (Table 3).

Table 2
Proximate analysis (percent±S.E.M.) of gilts sampled at early lactation (EL) and weaning (LL)[a,b]

Breed	Fat		Protein		Lactose	
	EL	LL	EL	LL	EL	LL
Meishan $n=5$	10.72 ± 0.5^{aA}	8.60 ± 0.5^{bB}	5.49 ± 0.2	5.12 ± 0.2	5.34 ± 0.5	5.84 ± 0.5
Crossbred $n=9$	8.91 ± 0.4^{bB}	6.49 ± 0.4^{cC}	5.41 ± 0.2^{D}	4.76 ± 0.2^{E}	4.90 ± 0.4	5.44 ± 0.4

[a] Numbers within columns with different superscripts are different at $^{ab}P<0.01$; $^{bc}P<0.001$.
[b] Numbers between EL and LL with different superscripts are different at $^{AB}P<0.01$; $^{BC}P<0.001$; $^{DE}P<0.05$.

Table 3
Solvation values (g water/g protein) and calcium concentrations (g/dl) in milks from gilts at early lactation (EL) and weaning (LL)[a,b]

Breed	Solvation		Calcium	
	EL	LL	EL	LL
Meishan $n=5$	2.36±0.16	2.08±0.16	0.204±0.01[a]	0.226±0.01
Crossbred $n=9$	2.18±0.12	1.96±0.13	0.178±0.01[bA]	0.210±0.01[B]

[a] Numbers within columns with different superscripts are significant at [ab]$P<0.05$.
[b] Numbers across rows with different superscripts are significant at [AB]$P<0.01$.

3.3. Fatty acid analysis

No breed differences were observed in milk fatty acid composition (Table 4). However, in the Meishan pigs, an increase was observed in 14:0 and 16:0 values while 18:1 values decreased from early- to late-lactation. Similar but insignificant changes between early- and late-lactation were observed in the crossbred (Table 4).

3.4. Litter characteristics

The Meishan sows consistently had larger litters at farrowing than the crossbred sows ($P<0.05$). There were no differences in the number born dead or mummified. The mean piglet weight for the crossbred piglets was higher than for the Meishan piglets. The same was true for mean piglet weaning weights (Table 5).

Table 4
Milk fatty acid analysis comparing milks from Meishan and crossbred multiparous sows. Samples were from early and late lactation (percent±S.E.M.)

Fatty acid	Meishans ($n=4$)		Crossbreds ($n=4$)	
	Early	Late	Early	Late
14:0	1.87±0.36[a]	2.68±0.20	2.23±0.55	2.79±0.60
16:0	20.87±0.48[a]	25.79±0.7	23.37±1.36	26.88±2.29
16:1 △ 9	0.71±0.06	0.52±0.05	0.64±0.11	0.45±0.06
16:1 △ 7	6.43±1.4	6.78±0.43	5.39±0.96	6.21±1.37
18:0	5.93±0.98	5.07±0.41	6.38±0.80	6.03±1.29
18:1 △ 9	41.28±1.66[a]	36.94±1.26	38.42±3.35	34.91±2.65
18:1 △ 7	3.35±0.20[a]	2.81±0.16	2.49±0.19	2.17±0.22
18:2 △ 6	13.45±0.51	13.52±0.57	15.00±1.50	14.56±0.81
18:3 △ 3	0.57±0.04	0.57±0.03	0.64±0.09	0.64±0.05
20:1 △ 9	0.52±0.05	0.49±0.04	0.32±0.13	0.22±0.14
20:4	0.74±0.10	0.75±0.02	0.66±0.05	0.60±0.06

[a] Early vs. late lactation significance <0.05.

Table 5
Litter characteristics of Meishan and crossbred pigs[a]

	Meishan ($n=5$)	Crossbred ($n=9$)
Litter size	13.8±1.00[a]	11.1±0.74[b]
Dead	1.2±0.4	1.0±0.31
Mean piglet wt at birth, kg	0.91±0.09[c]	1.43±0.07[d]
Mean piglet wt at weaning, kg	4.78±0.41[a]	5.94±0.31[b]

[a] Numbers across rows with different subscripts are significantly different at [a,b]$P<0.05$; [c,d]$P<0.001$.

4. Discussion

The newborn piglet is solely dependent on sow colostrum and milk for its nutritional energy source with glucose and fatty acid metabolism having major roles in energy metabolism (Duée et al., 1996). Nutrient partitioning to lean or adipose is affected by genetics as suggested by McNamara and Martin (1982). From this study, litter size was higher in the Meishans but mean of the birth weights were less than in the crossbred pigs. Additionally, the Meishan mean of the weaning weights were less than those of the crossbred piglets. Bazer et al. (1988) reported both decreased birth weights and weaning weights in Meishans when compared to Large Whites. Our data comparing crossbred piglets were similar. There were higher concentrations of milk fat in the Meishans as compared to the crossbred. It has been suggested that an increase in colostral or milk fat would provide improved piglet performance. Bishop et al. (1985) added triamcinolone plus soy oil to the prepartum diet of sows and observed that the colostrum had more fat but the diet also increased carcass fat in nursed pigs. Coffey et al. (1982) found no increase in weaned piglet weights as a result of increased milk yield/milk fat. We conjecture that no improvement in weaning weight is a reasonable finding if the assumption is that carcass fat weighs less than muscle fat. In contrast, according to Nissen et al. (1994), the addition of β-hydroxy-β-methylbutyrate to the diet of sows increased the percentage milk fat and also increased piglet weight. Further, similar results were reported by Averette and Odle (1997) who added a fat supplement to the diet of primiparous and multiparous sows resulting in increased piglet weight. In addition, differences in fatty acid composition between the Meishans and crossbreds were not observed. This was not surprising given the fact that both breeds were on the same diet. Fatty acids in the milk tend to reflect dietary fat composition rather than fatty acid composition of the body according to McNamara (1997).

Over time, casein solvation values correlated positively with protein concentration and negatively with calcium concentrations. This observation is consistent with data reported on bovine milk (Thompson et al., 1969).

Higher concentrations of ionic calcium in milk serum increase calcium bridges among individual casein molecules limiting the amount of water trapped in the micelle lattice. Unpublished work by Thompson in 1970 observed that poorly solvated micelles (<1.5 g water/g protein in bovine milk) were dramatically larger than highly solvated micelles (≥ 2.09 g water/g protein) when observed by transmission electron microscopy. These findings, the inverse relationship of size and solvation, were corroborated by Anema and Creamer (1993). They also related solvation to high amount of κ-casein present with no relation to calcium.

On the one hand, a study by Sood and Gaind (1979) postulated that voluminosity of the casein micelle increased as solvation increased without loss of protein. On the other hand, these researchers also found, as reported here, a negative correlation between calcium content and solvation. Although total casein of sow's milk (~4%) is higher than that of cow's milk (~2.5%), our observations show that casein micelles are solvated 17% more than the average cow's milk. Genetic variants of α_{s1}, β, and κ-casein have been associated with bovine micelle solvation. Therefore, the expectation of differences between Meishan and crossbred sows would not be unusual if, indeed, the caseins are also genetically variable. The importance of solvation in sow milk is uncertain. A possible explanation of its function might be that solvation influences protein retention time in the gut slowing the rate of digestion and absorption; i.e. the lower the solvation, the greater the retention time. Amino acids from milk proteins contribute little to the energy of the newborn but are important in the accretion of body protein (Girard et al., 1992). In this study, milk from crossbred sows had the lowest solvation ratios. Also, the piglets were heavier at weaning when compared to the Meishan piglets. It is not known whether the high solvation values reflect piglet performance in this study.

Calcium concentration in the Meishan milk was higher than that of the crossbreds at early-lactation and slightly higher at late-lactation. At early-lactation, calcium is advantageous for providing bone growth, thereby contributing to overall strength of the mammal. One study showed that in growing pigs, high serum calcium, as a result of feeding increased calcium in the diet, significantly depressed pig weights. Additionally, the immune response was not influenced as demonstrated by challenge with Brucella abortus (Galloway et al., 1989). Meishan pigs have better disease resistance to certain bacterial strains (Duchet-Suchaux et al., 1991) but there is no conclusive evidence that the high calcium concentrations observed in Meishan milk at early-lactation have any protective effects for the piglets, although the possibility exists. Improved immune response would contribute to overall well-being and survivability. Factors such as high calcium that are effective during early development, i.e. suckling, may not be as effective at a later stage of development, i.e. post-weaning.

5. Conclusion

A contributing factor to the success of Meishan piglets can be attributed to the quality of the sow milk. High milk-fat is advantageous to the newborn but may be contraindicated to the long-range goals of pork producers who are concerned with ways to increase piglet weights for early weaning without compromising the carcass lean:fat ratio, especially if there was a residual effect of high milk-fat on post-weaning pigs. Additionally, it is well known that milk contains growth factors and other modulators of growth including minerals. For example, the contribution of calcium to bone growth is well known but it also may relate to disease resistance especially during early-lactation. Physical properties of milk are also a consideration. Although slight differences in solvation of casein micelles were apparent between Meishan and crossbreds, the physiological significance cannot be determined from this study.

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