Type of Milk Consumed Can Influence Plasma Concentrations of Fatty Acids and Minerals and Body Composition in Infant and Weanling Pigs[1]

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ABSTRACT Two experiments using 42 crossbred neonatal pigs to compare the effects of caprine and bovine milk on growth, apparent nutrient digestibility and body composition were conducted. At age 72 h, pigs were removed from their dams and randomly divided into two groups, housed separately in stainless steel metabolism cages and were fed a predetermined amount (300 mL/kg body weight) of pasteurized, nonfortified whole, caprine or bovine milk. Body composition was determined using dual energy X-ray absorptiometry (DXA). In Experiment 1, 22 intact male pigs were used for a 31-d experimental period. There was no significant ($P > 0.05$) dietary effect on growth, apparent nutrient digestibility or body composition. Significant differences ($P < 0.05$), however, were observed in plasma of C 8:0, C 10:0 and C 12:0 concentrations. In Experiment 2, 20 pigs (10 intact males and 10 females) were used in a 2 × 2 factorial experiment for 52 d. Pigs fed caprine milk had higher ($P < 0.05$) plasma concentrations of C10:0 and C12:0 as well as Na, Mg and Zn than those fed bovine milk. At Day 52, pigs fed caprine milk had less body fat ($P < 0.001$) and higher ($P < 0.06$) bone mineral density than those fed bovine milk. Drymatter, N and total mineral intake of male pigs was higher ($P < 0.05$) than female pigs. Also, male pigs had higher ($P < 0.05$) plasma concentrations of C12:0 than females. This study demonstrates that the type of milk consumed can influence plasma concentrations of fatty acids, minerals and body composition in pigs. J. Nutr. 129: 132–138, 1999.

KEY WORDS: • *pigs* • *caprine and bovine milk* • *growth* • *body composition*

Studies have reported that 7–8% of human infants less than 3 mo of age are intolerant of bovine milk (Bock 1987, Gerrard et al. 1973, Host et al. 1988). Identifying a milk substitute for human infants who are intolerant of bovine and or soy milk is essential when human milk is unavailable. Because of the popular belief that it elicits fewer allergic symptoms, often associated with eczema, asthma, digestive disorders and neurotic indigestion, caprine milk may be fed to infants (Babayan 1981). Research investigations comparing the gross composition of caprine and bovine milk show similarities as well as differences in proteins, lipids, enzymes and minerals (Jennes 1980, Juarez 1986). For example, it was reported that fat globules in caprine milk are smaller than those in bovine milk (Le Mens 1985, Morand-Fehr and Flamant 1983). Caprine milk fat has ~35% short- and medium-chain fatty acids compared to 17% for bovine milk fat (Haenlein 1992).

Information on the nutritive value of caprine milk for human infants, although sparse, dates back to 1925. There is disagreement among the researchers regarding the effectiveness of caprine milk. For example, studies utilizing rats suggest negative results (Lee et al. 1962, Shurpalekar et al. 1964), whereas studies on humans report both positive (Mack 1953) and negative results (Daniels and Sterns 1925). Most of these studies did not adjust for the effects of the subject's age, sex or weight and in many instances sample size was not adequate. Results from more recent studies with malnourished children (Razafindrakoto et al. 1994) and with pigs (Fevrier et al. 1993) revealed no significant differences in growth rate and nutrient digestibility when caprine milk was compared to bovine milk.

There is limited scientific evidence available on the importance of whole, nonfortified caprine milk in human nutrition. In addition, little is know about the effect of caprine milk on body composition. In view of the importance of milk in providing minerals and vitamins to developing infants, the present study was designed to compare growth performance, nutrient availability and body composition of neonatal pigs fed whole, nonfortified, pasturized caprine and bovine milk. The neonatal pig is being used increasingly as a model for the human infant in studies of nutrient digestibility and body composition (Borum 1993, Moughan et al. 1990, Shulman, 1993).

MATERIALS AND METHODS

Experiment 1. The first experiment was designed to determine the effect of type of milk on growth performance, apparent nutrient

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TABLE 1

Comparative nutrient composition of caprine and bovine milk

Item	Caprine	Bovine
Protein, *g/100 g*	3.25	3.06
Total lipids, *g/100 g*	5.39	4.98
Total minerals, *g/100 g*	0.71	0.65
Gross energy, *kJ/g*	2.78	2.68
Moisture, *g/100 g*	88.99	89.14
Na, *mg/100 g*	30.00	46.70
K, *mg/100 g*	103.90	90.96
Zn, *mg/100 g*	0.74	0.82
P, *mg/100 g*	58.14	49.05

digestibility and body composition of infant pigs (0–4 wk of age). Twenty-two intact male crossbred pigs (Yorkshire × Hampshire × Duroc) from 16 litters (average initial body weight 2.1 kg; age 72 h) were used for a 31-d experimental period. All pigs received colostrum from their dams and were injected intramuscularly with 2 mL of iron dextran, containing 100 g Fe/L. Pigs were housed in individual, stainless steel metabolism cages (58.8 × 60 × 62.5 cm; Lab products, Maywood, NJ) with slatted floors that were designed to separate urine and feces. The cages were in an environmentally controlled room with temperature maintained at ~28°C; relative humidity ranged from 35 to 45%, and artificial light was provided continuously. All pigs were vaccinated with Mycoplasma Hyopneumoniae Bacterin (Solvay Animal Health, Mendota Heights, MN) at Days 14 and 28.

Experiment 2. The second experiment was designed to determine the effect of type of milk and sex on growth performance, apparent nutrient digestibility and body composition of infant (0–4 wk of age) and weanling (4–8 wk of age) pigs. Twenty pigs, 10 intact males and 10 females, (average initial body weight 2.3 kg; age 72 h) were used for a 52-d experimental period. Similar procedures as those described in Experiment 1 were used for animals and housing in Experiment 2. All animal care and experimental protocols were approved by The University of Georgia's Animal Care and Use Committee.

Diets. All pigs were weighed and randomly allocated to receive either fresh, pasteurized, nonfortified, whole caprine or bovine milk. The nutrient composition of the milks are presented in **Table 1**. Caprine milk was obtained from Fort Valley State University Caprine Research Center, Fort Valley, GA. Bovine milk was obtained from The University of Georgia Dairy Research Farm, Athens, GA. Caprine and bovine milk were provided as one batch and frozen (−20°C) separately in 5 L containers. Each container of milk was thawed in a cold water bath before use.

Robotic feeding system. The robotic-based feeding system is a Foxy 200™ programmable fraction collector connected to a peristaltic pump and valve controller (ISCO, Lincoln, NE). A complete description, programming, and accuracy and precision for the feeding system is described in detail by Firotto et al. (1993). Robotic action was performed by the fraction collector and dispensed caprine or bovine milk via polypropylene collection funnels to each pig. The milk was stored in refrigerated acrylic reservoirs (Jet Spray Corporation, Boston, MA) and maintained at 4 ± 1°C. The refrigerated acrylic reservoirs were modified to stir the milk at predetermined intervals (10 times per hour), utilizing output signals from the fraction collector to relay switches on the valve controller. In Experiment 1, the milk was pumped from the reservoirs through a heating system and warmed to 35 ± 2°C before being dispensed to the pigs. The heating system consisted of electric heat elements spiraled around a coil of glass tubing and was controlled by an electronic voltage regulator with a visible intensity indicator for continuous monitoring. However, it was noted that the heating element caused the milk to coagulate after 8 h in the glass tubing. Subsequently, the glass tubing was monitored and flushed with distilled water at 8 h intervals to remove any coagulated milk. For Experiment 2, the heating element was not used and the milk was dispensed to the pigs at 4 ± 1°C.

Feeding trial. In each experiment for the first 24 h, the pigs were trained to drink milk from stainless steel food pans by hand-feeding them every 2 h (0800, 1000, 1200, 1400, 1600, 1800, 2000, and 2200 h) with no feeding between 2200 and 0800 the next morning. The robotic feeding system was used to feed the pigs beginning on Day 2. Pigs received their respective diets at a set level of 300 mL/kg body weight per day. The total daily allowance of milk was delivered over 22 feedings at 60 min intervals, and the remaining 2 h (0800–1000) were used to sanitize the feeding system. The first 7 d were used as an adjustment period to allow the pigs to adapt to diets and metabolism cages. Subsequently, the pigs were fed for a 31-d and 52-d experimental period in Experiment 1 and 2, respectively. Pigs were weighed every-other-day. The feeding system was adjusted according to the pig's individual weight to ensure that each pig received its desired individual weight-adjusted volume of milk. The peristaltic pump's output was varied to reflect the increasing volume of milk required based on the weight gain of the pigs.

Body composition. Body composition was determined using dual energy X-ray absorptiometry (DXA; QDR-1500/W, Hologic Inc., Walthman, MA). Individual scans were analyzed by using the Adult Whole Body Software (Version 7.01, Hologic Inc., Walthman, MA). The software used to calculate these estimates assumed that the lean body mass of the pig was 73.2% water, which is comparable to expected water content of body mass of pigs. The DXA scans were performed according to the procedures of Brunton et al. (1993). The technique is based on the relative tissue absorbance of X-radiation at two energy levels and is very stable (Lang et al. 1991, Sartoris and Resnick 1990). The DXA system estimates bone mineral content (BMC) and bone mineral density (BMD). This estimate is made by comparing the energy levels passed through the pig with the energy levels passed through calibrated samples of bone, soft tissue and air. Quality control for DXA measures was verified by scanning a Hologic calibration phantom of known mineral content before testing (Kirchner et al. 1995). Using the tissue calibration bar, energy levels were determined for equivalent lean and fat tissues. With this calibration, the fat mass, lean mass and percent fat were estimated.

In Experiments 1 (31 d) and 2 (52 d), after withholding both feed and water for 24 h, pigs were anesthetized with intramuscular injections of 20 mg Ketamine/kg, 2 mgXylazine/kg, and 0.05 mg Atropine sulfate/kg to assure that they remained motionless for the duration of the DXA scan (8–10 min). The pigs were placed uncovered on the scan table on their stomachs, with the legs extended from the body. The X-ray source was positioned underneath the scan table that supported the pig, with the detector housed in an arm above the pig. During a scan, the source and detector moved together over the area covered by the pigs.

Sample collection

Plasma. Blood (8 mL) was taken from each pig by jugular puncture and collected in heparinized tubes at 72 h of age in Experiments 1 and 2. On Days 7, 14, 21, 28, 35 and 42, blood was taken from each pig 1 h after a meal. Blood samples were taken between 0800 and 0900 h while the robotic feeding system was being sanitized. Blood was centrifuged at 2,500 × *g* for 20 min and the plasma was harvested and frozen (−20°C) for subsequent analysis.

Apparent nutrient digestibility. Duplicate samples of caprine and bovine milk were collected before feeding and frozen (−20°C) until analyzed. For each experiment, 5-d energy and nitrogen balance trials were conducted (Day 23 to 28 in Experiment 1, and Day 23 to 28 and 37 to 42 in Experiment 2). Total feces was collected twice daily, weighed, and frozen (−20°C). Total urine was collected twice daily in 1-L vessels containing 10 mL of 6 mol HCl/L. A 10% aliquot of the total urine volume was taken and frozen (−20°C) until analyzed.

Sample analysis.

Plasma mineral concentration. Duplicate plasma samples were analyzed for concentrations of Na, K, Zn, Mg and Fe (AOAC, 1990) using a flame atomic absorbance spectrophotometer (Scan 1, Model 150, Thermo Jarrell Ash Corporation, Franklin, MA). Comparison with the standard curve was used to determine the amount of each

TABLE 2

Growth performance and feeding efficiency of male and female pigs fed caprine bovine milk (Experiment 2)[1]

	Main effect							
	Diet				Sex			
Item	Caprine	Bovine	SE	*P*-value	Male	Female	SE	*P*-value
Initial body weight, *kg*	2.18	2.17	0.08	0.77	2.23	2.12	0.08	0.26
Final body weight, *kg* (52 d)	9.65	10.58	0.46	0.08	10.55	9.73	0.43	0.20
Gain, *kg*								
0–28 d	4.47	4.73	0.14	0.73	4.95	4.26	0.28	0.25
28–49 d	3.01	3.37	0.23	0.10	3.37	2.95	0.23	0.92
0–49 d	7.48	8.10	0.22	0.09	8.32	7.21	0.42	0.29
Feed intake, *kg*								
0–28 d	27.86	27.37	0.84	0.50	29.12	28.06	0.30	0.64
28–49 d	43.17	46.69	1.59	0.35	46.75	43.11	2.59	0.42
0–49 d	71.03	74.06	2.06	0.19	75.87	71.17	2.06	0.49
Gain/feed, *kg/kg*								
0–28 d	0.16	0.15	0.02	0.69	0.16	0.13	0.49	0.58
28–49 d	0.07	0.07	0.01	0.23	0.07	0.06	0.05	0.15
0–49 d	0.11	0.11	0.01	0.25	0.11	0.10	0.01	0.25

[1] Data are means and SE, $n = 20$; (five pigs of each sex were fed each type of milk).

mineral present in each sample. Inorganic P concentration was determined with the method described by Sigma Chemical (1991).

Apparent nutrient digestibility. Fecal samples were thawed, thoroughly mixed, and a 20% subsample was taken and dried at 55°C for 48 h, air-equilibrated for 24 h and ground in a Wiley Mill (Arthur A. Thomas, Philadelphia, PA) through a 1-mm screen. Milk was also thawed and mixed. One g of milk and 1 g feces were weighed out, dried at 100°C and analyzed for dry matter and ether extract (AOAC 1990). Duplicate samples of milk, feces and urine were analyzed for N and total minerals (AOAC, 1990). Gross energy was determined by adiabatic bomb calorimetry (Parr Instrument Co., Moline, IL). And Zn, Mg, Na and K content (AOAC, 1990) was determined by using a flame atomic absorbance spectrophotometer (Scan 1, Model 150, Thermo Jarrell Ash Corporation, Franklin, MA) following a nitric acid-perchloric acid wet ash. Comparison with the standard curve was used to determine the amount of each mineral present in each sample. Inorganic P concentration was determined with the method described by Sigma Chemical (1991).

Milk and plasma fatty acids. Duplicate plasma and milk samples were analyzed for fatty acids after lipid extraction (Erickson and Dunkley 1964) and methylation (Mason and Waller 1964). Fatty acid methyl esters were separated and quantified using a gas chromatograph (Model 5890A equipped with autosampler, flame-ionization dector, and Model 339A integrator; Hewlett Packard, Avondale, PA) fitted with a narrow-base capillary column (Megabore DB225, J&W Scientific, Folsom, CA).

Statistical Analysis. In Experiments 1 and 2, data were analyzed as a completely randomized design using the general linear model procedures of SAS (1990) with the individual pig serving as the experimental unit. Results are reported as least-squares means ± pooled SEM. In Experiment 2, dietary treatments were arranged in a 2 x 2 factorial of caprine or bovine milk and male or female. Data from the factorial arrangement of treatments were analyzed as a randomized design. The model included diet and sex and the interaction between diet and sex. Individual pigs served as the experimental unit. Significant level was set as $P < 0.05$, unless indicated otherwise.

RESULTS

Experiment 1. There were no significant differences in final body weights of pigs fed caprine and bovine milk (6.5 ± 0.7 vs. 6.6 ± 0.8 kg). Both groups of pigs gained at a rate of 140 g daily, resulting in over a 200 % increase in body weight during the first month of life. Also, there were no significant differences in feed intake (27.3 ± 3.8 vs. 28.9 ± 2.6 kg), gain/feed ratio (0.17 ± 0.1 vs. 0.16 ± 0.4 kg/kg), apparent digestibility of dry matter (99.6 ± 0.7 vs. 99.7 ± 0.2%), total minerals (92.4 ± 0.2 vs 91.2 ± 0.3%), energy retention (94.3 ± 1.3 vs. 94.6 ± 0.1%), or N retention (57.5 ± 2.5 vs. 53.0 ± 3.7%). No significant differences due to milk type were observed in body composition in regard to fat (3.9 ± 0.6 vs 3.5 ± 0.3 g/100 g) fat mass (150.5 ± 29.2 vs 138.3 ± 23.9 g) lean mass (3814.6 ± 124 vs 3803.4 ± 129 g), bone mineral content (45.2 ± 2.2 vs 46.6 ± 2.7 g) and bone mineral density (0.51 ± 0.2 vs 0.5 ± 0.1 g/cm^2) in pigs fed caprine milk and bovine milk, respectively.

Significant differences, however, were observed in plasma fatty acid concentrations. Pigs fed caprine milk had higher ($P < 0.05$) plasma concentrations of C 8:0 (0.86 ± 0.15 vs. 0.17 ± 0.15 g/100 g), C 10:0 (1.05 ± 0.24 vs. 0.16 ± 0.24 g/100 g) and C 12:0 (1.47 ± 0.18 vs. 1.05 ± 0.2 g/100 g) at Day 14 than those fed bovine milk. Plasma fatty acid concentrations of C 10:0 (0.54 ± 0.1 vs. 0.02 ± 0.1 g/100 g) and C 12:0 (1.25 ± 0.1 vs. 0.55 ± 0.2 g/100g) were also higher ($P <$ 0.05) on Day 28 in pigs fed caprine milk than in those fed bovine milk. At Days 14 and 28, plasma concentration of C 16:1 in pigs fed bovine milk was higher ($P < 0.05$) than in those fed caprine milk (2.53 ± 0.2 vs. 1.34 ± 0.3 g/100 g and 2.39 vs. 1.41 g/100 g, respectively), whereas the concentration of C 18:2 in pigs fed caprine milk at Days 14 and 28 (14.32 ± 0.3 vs. 11.69 ± 0.4 g/100 g and 18.03 ± 0.4 vs. 14.52 ± 0.6 g/100 g, respectively) was higher ($P < 0.05$) than those fed bovine milk.

Experiment 2. There was no significant diet X sex interaction observed for body weight or feed efficiency. Final body weight at Day 49 tended to be lower ($P < 0.08$) in pigs fed caprine milk compared to those fed bovine milk **(Table 2)**. Both groups of pigs more than tripled their body weight with an average daily growth rate of 137 and 162 g for pigs fed caprine and bovine milk, respectively. The type of milk or sex, however, did not affect feed intake or the gain/feed ratio. Significant diet X sex interaction was not observed for intake or digestibility of nutrients at Days 28 and 42. The intake of

TABLE 3

Apparent nutrient and energy availability at days 28 and 42 in male and female pigs fed caprine or bovine milk (Experiment 2)[1]

	Main effect							
	Diet				Sex			
Item	Caprine	Bovine	SE	*P*-value	Male	Female	SE	*P*-value
Day 28								
Dry matter intake, *g/d*	816.33	840.29	22.12	0.47	874.14	782.48	21.80	0.02
Dry matter digestibility, %	98.20	97.93	0.26	0.46	97.92	98.20	0.25	0.46
Nitrogen intake, *g/d*	4.58	4.47	0.19	0.70	4.62	4.44	0.19	0.52
Nitrogen retention, %	56.81	56.85	4.10	0.99	58.27	55.39	4.04	0.63
Energy intake, *MJ/d*	2.49	2.44	0.05	0.55	2.54	2.40	0.05	0.09
Energy retention, %	88.75	86.05	1.94	0.35	84.77	90.04	1.92	0.09
Total minerals intake, *g/d*	5.73	5.39	0.19	0.24	5.71	5.41	0.19	0.30
Total minerals digestibility, %	86.27	85.38	2.17	0.44	87.23	84.42	2.19	0.26
Day 42								
Dry matter intake, *g/d*	1220.79	1231.64	36.49	0.84	1367.13	1085.30	35.96	0.001
Dry matter digestibility, %	98.31	98.22	0.11	0.60	98.26	98.28	0.11	0.96
Nitrogen intake, *g/d*	7.15	6.73	0.18	0.10	7.32	6.57	0.18	0.01
Nitrogen retention, %	67.04	64.61	1.90	0.39	68.32	63.33	1.87	0.10
Energy intake, *MJ/d*	3.78	3.65	0.14	0.54	3.95	3.49	0.14	0.04
Energy retention, %	84.60	84.33	1.48	0.90	85.19	83.74	1.46	0.51
Total minerals intake, *g/d*	8.58	8.10	0.32	0.28	8.75	7.90	0.31	0.09
Total minerals digestibility, %	89.12	86.43	1.17	0.07	88.79	86.81	2.78	0.32

[1] Data are means and SE, $n = 20$; (five pigs of each sex were fed each type of milk).

dry matter, total minerals, N and energy **(Table 3)** were unaffected by the type of milk. Also, the type of milk did not affect the digestibility of dry matter and ash or the retention of energy and N at Days 28 or 42. There was a significant sex effect at Days 28 and 42 (Table 3). Dry matter intake of male pigs was higher ($P < 0.05$) than those of female pigs at Days 28 and 42. Also, at Day 42, N and energy intake were higher ($P < 0.05$) in male pigs than in female pigs. There was no significant sex effect on digestibility of dry matter and total minerals or the retention of energy and N on Days 28 or 42.

The results of Experiment 2 revealed no significant diet X sex interactions for plasma fatty acid concentrations. At Day 28, plasma concentration of C12:0, C18:2, and C 18:3 were higher ($P < 0.05$) in pigs fed caprine milk than in those fed

TABLE 4

Concentrations of plasma fatty acids at days 28 and 42 in male and female pigs fed caprine or bovine milk (Experiment 2)[1]

	Main effect							
	Diet				Sex			
Fatty acid	Caprine	Bovine	SE	*P*-value	Male	Female	SE	*P*-value
	g/100 g							
Day 28								
10:0	1.30	1.14	0.10	0.34	0.73	0.57	0.16	0.37
12:0	2.22	1.88	0.10	0.05	1.61	1.48	0.35	0.80
16:0	22.64	23.40	0.29	0.09	22.95	23.08	0.29	0.76
18:0	11.50	12.56	0.15	0.001	12.13	11.93	0.15	0.40
18:1	30.62	31.97	0.50	0.09	31.22	31.37	0.50	0.84
18:2	13.65	10.88	0.22	0.001	12.53	12.00	0.15	0.10
18:3	2.65	1.25	0.25	0.004	2.09	1.80	0.25	0.44
Day 42								
10:0	1.50	1.13	0.11	0.05	0.39	0.25	0.11	0.42
12:0	82.11	1.82	0.10	0.09	2.69	2.23	0.17	0.003
16:0	22.28	23.76	0.36	0.02	22.22	23.83	0.36	0.01
16:1	3.16	3.58	0.22	0.17	2.85	3.85	0.22	0.01
18:0	10.62	12.22	0.30	0.004	11.11	11.73	0.29	0.18
18:1	30.46	31.75	0.64	0.20	29.56	32.64	0.64	0.009
18:2	12.00	10.12	0.39	0.009	11.67	10.45	0.39	0.05
18:3	1.87	1.34	0.43	0.41	1.75	1.46	0.43	0.64

[1] Data are means and SE, $n = 20$; (five pigs of each sex were fed each type of milk).

TABLE 5

Plasma Na, Mg, K, P, Zn and Fe concentrations in male and female pigs fed caprine or bovine milk (Experiment 2)[1]

	Main effect							
	Diet				Sex			
Mineral	Caprine	Bovine	SE	*P*-value	Male	Female	SE	*P*-value
	mmol/L				*mmol/L*			
Na								
Day 7	100.52	94.26	0.84	0.001	98.14	96.67	0.84	0.29
Day 28	100.17	99.84	1.80	0.003	92.58	93.78	2.37	0.73
Day 42	93.93	83.37	2.31	0.02	90.84	86.46	2.31	0.27
Mg								
Day 7	0.87	0.85	0.00	0.10	0.88	0.85	0.00	0.003
Day 28	0.69	0.64	0.00	0.02	0.69	0.64	0.00	0.04
Day 42	0.74	0.61	0.00	0.07	0.74	0.61	0.00	0.10
K								
Day 7	4.97	4.64	0.09	0.03	4.76	4.85	0.09	0.55
Day 28	6.17	5.31	0.18	0.02	5.79	5.84	0.18	0.74
Day 42	4.18	4.02	0.04	0.04	4.16	4.04	0.04	0.52
P								
Day 35	2.40	1.85	0.13	0.02	2.33	2.23	0.13	0.26
Day 42	1.87	1.68	0.02	0.10	1.90	1.66	0.02	0.06
	μmol/L				*μmol/L*			
Zn								
Day 7	11.90	11.04	0.02	0.03	11.50	11.50	0.02	0.97
Day 21	12.00	9.50	0.40	0.02	10.83	10.70	0.40	0.81
Day 28	11.00	9.50	0.27	0.03	10.20	10.16	0.27	0.67
Day 42	15.11	14.04	0.27	0.03	16.00	13.30	0.27	0.05
Fe								
Day 21	10.10	9.10	0.27	0.10	9.80	9.30	0.27	0.49
Day 28	9.10	8.40	0.18	0.03	8.60	8.90	0.18	0.20

[1] Data are means and SE, $n = 20$; (five pigs of each sex were fed each type of milk).

bovine milk **(Table 4)**. Plasma concentration of C18:0 was higher ($P < 0.05$) in pigs fed bovine milk than in those fed caprine milk, whereas C 16:0 and C 18:1 tended to be higher in bovine milk ($P < 0.09$). There was no significant effect of sex on plasma fatty acid concentrations at Day 28. Plasma concentrations of C10:0 and C18:2 were higher ($P < 0.05$) at Day 42 in pigs fed caprine milk than in those fed bovine milk, whereas pigs fed bovine milk had higher ($P < 0.05$) plasma concentrations of C16:0 and C18:0 than pigs fed caprine milk. At Day 42, male pigs had higher ($P < 0.05$) plasma concentration of C12:0 and female pigs had higher concentration of C16:0, C16:1, and C18:1.

There was no significant diet X sex interaction observed for plasma mineral concentration. The plasma concentration levels of Na, Mg and Zn were generally higher on Days 7, 28 and 42 in pigs fed caprine milk compared to those fed bovine milk **(Table 5)**. Further, higher ($P < 0.05$) plasma concentration of Zn was also observed at Dat 21 in pigs fed caprine milk versus those fed bovine milk. Data also indicated that on Day 28, plasma concentrations of K and Fe were higher ($P < 0.05$) in caprine milk-fed pigs. Phosphorus was higher ($P < 0.05$) on Day 35 and tended to be higher ($P < 0.10$) on Day 42 in those fed caprine milk. An examination of sex effect indicated that female pigs had higher levels of Mg than male pigs on Days 7 and 28 ($P < 0.05$). At Day 42, males had higher levels of ($P < 0.06$) and Zn ($P < 0.05$) than females.

Body composition of pigs at Day 52, revealed by estimates derived from dual-energy absorptiometry (DXA), are presented in **Table 6**. There was no significant diet X sex interaction observed. The DEXA scans showed that pigs fed caprine milk had 36.3% less body fat and 42.7% less fat mass than pigs fed bovine milk ($P < 0.05$). Further, BMD was 6.6% higher ($P < 0.06$) in pigs fed caprine milk compared to those fed bovine milk. An examination of sex effect revealed that female pigs had 25.1% more ($P < 0.05$) body fat and fat mass tended to be greater (21.4%, $P < 0.10$) than in male pigs. There was no diet or sex effect on lean mass or BMC at Day 52.

DISCUSSION

The nutrient composition of caprine and bovine milk reported in this study is in agreement with what has been reported in previous studies by Haeinlein and Caccesse (1984) and Juarez and Ramos (1986). Further, according to Edelsten (1988) and Haenlein (1992), the various components of caprine milk fat and fatty acids differ from bovine milk in both chain length and degree of saturation. Compared to bovine milk, caprine milk is higher in the content of short-chain fatty acids (6:0, C 8:0 and C 10:0) because of the high percentage of C 10:0 (Dils 1986, Edelsten 1988, Juarez 1986). In addition, caprine milk in general is higher in the minerals calcium, phosphorus, potassium and chlorine than bovine milk (Morand-Fehr and Flamant 1983).

In regard to growth performance, the pigs in the present study drank the caprine and bovine milk readily, remained healthy throughout the experiments and their final body weight was similar at Day 28. At Day 52, the final weight of

TABLE 6

Growth and body composition in male and female pigs fed caprine or bovine milk at d 52 (Experiments 2)[1,2]

	Main effect							
	Diet				Sex			
Item	Caprine	Bovine	SE	*P*-value	Male	Female	SE	*P*-value
Initial body weight, *kg*	2.18	2.17	0.08	0.77	2.23	2.12	0.08	0.26
Final body weight, *kg*	9.65	10.58	0.46	0.08	10.55	9.73	0.43	0.20
BMC[3], *g*	74.26	75.48	6.70	0.89	80.54	69.20	6.70	0.24
BMD[4], *g/cm*^{2}	0.76	0.71	0.02	0.06	0.74	0.73	0.02	0.65
Fat, g/100 *g*	3.45	5.42	0.32	0.001	3.94	4.93	0.32	0.04
Fat mass, *g*	300.66	524.92	38.20	0.001	373.51	452.07	35.64	0.10
Lean mass, *g*	9085.80	8905.89	376.26	0.74	9165.92	8771.59	334.11	0.51

1 Data are means and SE, $n = 20$; (five pigs of each sex were fed each type of milk).
2 Changes in body composition estimated by duel-energy X-ray absorptiometry (DXA).
3 BMC = Bone mineral content.
4 BMD = Bone mineral density.

pigs fed bovine milk tended to be more than pigs fed caprine milk. However, this difference could be mainly due to the fact that the pigs fed bovine milk had more body fat than those fed caprine milk. These results suggest that caprine milk supports growth similar to that of bovine milk. Little is known, however, about the growth performance, nutrient availability or body composition of infant or weanling pigs fed whole, nonfortified caprine milk, or the effect of caprine milk on the growth performance of human infants. Recently, one related study noted that, when severely malnourished children (ages 1–5 y) were fed either caprine or bovine milk fortified with vegetable oil, sugar, vitamins and minerals, there was no difference in growth rate due to treatment (Razafindrakoto et al. 1994). Findings from this study, however, can not be generalized because Razafindrakoto et al.'s (1994) investigation used powdered caprine and bovine milk for 15 d to rehabilitate undernourished children.

In the present study, nutrient availability to pigs fed caprine and bovine milk were similar. Findings from these experiments are in agreement with Sawaya et al. (1984) who reported similarities in in vitro protein digestibility and protein efficiency ratio of caprine and bovine milk. Further, Fevrier et al. (1993) supplemented caprine and bovine milk with barley and reported that pigs (35 kg) digested similar amounts of nutrients from caprine and bovine milk. The nutrient availability of whole bovine milk has been commonly studied, whereas less is known about the nutritive value of nonfortified caprine milk fed to human infants.

Though fatty acid digestibility was not determined in the present study, our examination of circulating plasma levels of fatty acids showed greater concentration of C 10:0 and C 12:0 in pigs fed caprine milk compared to those fed bovine milk. This was an expected finding given that caprine milk fat has about 35% short- and medium-chain fatty acids compared to 17% for bovine milk fat (Haenlein 1992). There was evidence of a greater concentration of circulating plasma levels of C18:2 in pigs fed caprine milk observed in the present study. In one digestibility study, Février et al. (1993) reported that caprine milk fatty acids, especially C18:2, tended to be better absorbed than the bovine milk fatty acids when fed to pigs. Variations in circulating plasma levels of fatty acid from caprine milk in male and female pigs has not been reported in previous studies. Results presented here imply that male pigs had a greater plasma concentration of C 12:0 and C 18:2 than female pigs, whereas female pigs had higher plasma levels of C 18:1. The extent to which circulating plasma levels of fatty acids noted in this study would be observed in human infants has not been reported. It has been speculated, however, that the fat globules in caprine milk may facilitate greater digestion and absorption than bovine milk. In caprine milk, fat globules are smaller, do not cluster and have greater surface area than those of bovine milk (Jenness and Parkash 1971).

Caprine milk, in general, is higher in the minerals potassium, sodium and phosphorus than bovine milk (Morand-Fehr and Flamant 1983). Results from Experiment 2 showed that circulating plasma levels of Na, K and P were higher in caprine milk-fed pigs than in those fed bovine milk. In addition, Park et al. (1986) fed dehydrated caprine and bovine milk to anemic rats and reported that bioavailability of Fe from caprine milk was higher than Fe from bovine milk. In the present study, pigs fed caprine milk had higher plasma concentration of Fe at Day 28 compared to those fed bovine milk. These findings suggest that caprine milk-fed pigs may have had more Fe available for hemoglobin and oxygen transport to cells. Further studies are necessary to determine the basis for higher plasma concentrations in pigs fed caprine milk compared to those fed bovine milk. In addition, there is a need to compare the plasma mineral concentrations of human infants fed caprine and bovine milk to those observed in the pigs in this study.

The pigs fed caprine milk generally had higher bone mineral density, less body fat and less fat mass than those fed bovine milk. The greater bone density in the caprine milk-fed pigs may have been due to their greater concentrations of plasma minerals. For example, pigs fed caprine milk had higher circulating levels of P and Mg, suggesting that these minerals were available for the development and maintenance of bones. In regard to the observed difference in percentage of body fat in the pigs, this finding may be due to the variations in fatty acid composition of caprine and bovine milk. As noted earlier, caprine milk has a higher percentage of short- and medium-chain fatty acid compared to bovine milk. This difference, therefore, in the fatty acid composition of the milks may account for the differences observed in the percentage of body fat in the pigs. Several reviews have reported on the absorption, transport, metabolism and clinical use of medium-chain fatty acids (Bach and Babayan 1982, Senior 1968). According to Bach and Babayan (1982) short- and medium-chain fatty acid are digested, absorbed, and transported easily and rapidly; have a very low tendency to deposit as body fat; and are a source of abundant and rapidly available energy. In addition, Hashim and Tantibhedyangkul (1987) reported that long chain triglyceride-fed rats were significantly heavier, with larger epididymal and subcutaneous fat pads, and larger number and size of adipocytes than the medium-chain triglyceride-fed rats. The effects of feeding infants a diet containing short- and medium-chain triglycerides early in life may influence body composition later in life by reducing obesity. For example, Hashim and Tantibhedyangkul (1987) concluded that the type of fat in the diet fed early in life can influence the development of adipose tissue.

The pig model used in these experiments confirmed that whole, nonfortified caprine milk supports growth similar to whole, nonfortified bovine milk. Further, we were able to determine that there was greater bone mineral density and lower body fat in pigs fed caprine milk. The body composition of growing animals and infants is essential knowledge for optimizing nutritional management for the support of growth and development. In conclusion, it can be inferred from the pig model used in these experiments that caprine milk can be effectively used as an alternative milk source for human infants that are intolerant of bovine milk.

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