Lactation in the Horse: The Mineral Composition of Mare Milk

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ABSTRACT Changes in the mineral composition of mare milk during lactation were studied. Milk samples were obtained from five Thoroughbred mares one to three times weekly from the first to the eighth week of lactation and from two of the mares for an additional 8 wk. Samples averaging 500 mL were obtained after oxytocin was administered to the mares. Each sample was analyzed for total solids, ash, calcium, phosphorus, magnesium, sodium, potassium, copper and zinc. The concentration of all constituents except sodium and potassium decreased throughout lactation. The rates of decline of ash, calcium, phosphorus and magnesium concentration were similar, but the rates of decline of the other elements differed. Thus, the mineral composition of mare milk should be described in terms of the stage of lactation of the mare. The total solids and ash content of mare milk were 12 and 0.61% respectively, at the end of the first week of lactation, 10.5 and 0.45% at 4 wk, 10 and 0.38% at 8 wk and 10.2 and 0.32% at 16 wk. The calcium, phosphorus and magnesium concentrations at the end of the same periods were 1345, 943 and 118 μg/g of milk at 1 wk; 1070, 659 and 86 at 4 wk; 831, 574 and 58 at 8 wk and 700, 540 and 43 μg/g of milk at 16 wk. Cooper and zinc concentrations were 0.85 and 3.1, 0.55 and 2.2, 0.29 and 1.9 and 0.28 and 1.8 μg/g of milk at 1, 4, 8 and 16 wk, respectively. J. Nutr. *116*: 2142–2147, 1986.

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The organic composition of mare milk has been the subject of numerous investigations and reviews (1–3). A recent study reported that at midlactation (24–54 d postpartum mare milk averaged 10.5% dry matter, 1.29% fat, 1.93% protein, 6.91% sugar and 50.6 kcal/100 g (4). However, studies of the mineral composition of mare milk have been few and scattered. Most studies were done many years ago before the advent of modern methods of mineral analysis. The following study was undertaken to provide information about the mineral composition of mare milk for a better understanding of the nutrition of the lactating mare and her foal.

MATERIALS AND METHODS

The composition of milk of five Thoroughbred mares was studied. The mares averaged 500 kg in body weight, varied in age from 11 to 20 yr and had borne 1 to 9 foals in previous years. The mares and foals for the present study were housed in box stalls. The mares were fed a mixed grain and molasses concentrate feed and a mixed alfalfa and grass hay. The grain mixture contained about 13% crude protein; 0.5% calcium and 0.3% phosphorus (4).

Milk samples were obtained once on d 3,

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6 and 7 from four of the mares during the first week of lactation, then two to three times per week from each mare during the second through eighth weeks of lactation. Thereafter, two mares were sampled two to three times during each successive 3 wk period.

One to two hours before a milk sample was obtained, the foal was muzzled to prevent it from nursing from the mare. The mare was given 20 IU of oxytocin by intramuscular injection. The foal was then allowed to nurse one teat while the opposite was milked by hand. Every effort was made to completely evacuate the gland. Milk was collected in acid-washed glassware. The average sample size that was obtained was 500 mL.

All analyses were done in duplicate. Total solids were estimated after drying samples at 100°C in a forced-draft oven for 12 h. The dried milk samples were then ashed at 550°C overnight in a muffle furnace. The ash was taken up in 3 *N* HCl for mineral determinations. Magnesium, zinc and copper were estimated in the acid-soluble ash by flame atomic absorption spectrophotometry (Perkin-Elmer, Model 3058) and calcium by the same procedure in the presence of lanthanum chloride. Sodium and potassium were measured by flame-emission spectroscopy (Instrumentation Laboratory, Model 343). Phosphorus was determined by stannous chloride–hydrazine reduction of phosphomolybdic acid in an automated Technicon procedure.

The adequacy of these procedures was assessed by preparing and analyzing bovine nonfat milk powder (Standard Reference Material 1549) obtained from the National Bureau of Standards. The bovine nonfat milk powder reference is certified to contain $1.30 \pm 0.05\%$ Ca, $1.06 \pm 0.02\%$ P, $0.12 \pm 0.003\%$ Mg, $1.69 \pm 0.03\%$ K, $0.497 \pm 0.01\%$ Na, 0.7 ± 0.1 μg/g Cu and 46.1 ± 2.2 μg/g Zn. The result of six separate and independent analyses of the reference material using our procedures gave the following results: $1.31 \pm 0.014\%$ Ca, $1.06 \pm 0.01\%$ P, $0.124 \pm 0.002\%$ Mg, $1.55 \pm 0.11\%$ K, $0.468 \pm 0.05\%$ Na, 0.79 ± 0.1 μg/g Cu and 46.7 ± 2.2 μg/g Zn.

RESULTS AND DISCUSSION

The average weekly mineral composition of mare milk is given in table 1. The concentration of total solids, ash and all elements was highest during the first week of lactation. The concentration of these constituents then decreased. The concentration of total solids decreased 12.5% during the first 4 wk of lactation, 5% during the next 4 wk and then remained constant for the next 8 wk. In contrast, the ash content of mare milk declined more rapidly, decreasing 26% during the first 4 wk, 16% during the next 4 wk and an additional 16% during the next 8 wk or approximately 50% in 16 wk. The decline in calcium, phosphorus and magnesium concentration in milk was similar to the decline in ash content probably because these elements comprise the largest component — about 40% — of the ash of mare milk (table 1). Calcium, phosphorus and magnesium decreased 20, 30 and 27%, respectively, during the first 4 wk of lactation, 22, 12 and 32% during the next 4 wk and 16, 6 and 26% during the next 8 wk. The total percentage declines were 48, 43 and 64%, respectively, for calcium, phosphorus and magnesium. The mineral ratios changed during lactation. The Ca:P ratio was 1.45:1 during the first week and 1.3:1 during wk 15–17. During the same periods the Ca:Mg ratio changed from 11:1 to 16:1.

The concentration of sodium and potassium in mare milk decreased about 30% during the first 4 wk, then fluctuated throughout the remainder of the 16-wk observation period. The percentage decrease in zinc concentration was 41% for the first 5 wk; thereafter the concentration of zinc remained constant. Among the minerals analyzed, copper displayed the greatest decrease in concentration, declining 35% in the first 4 wk, 47% in the next 4 wk and remaining constant for the next 8 wk.

Thus, the concentration and ratio of mineral elements in mare milk is continually changing and it is difficult to describe an "average" mineral composition of the milk. Linton (5) pointed out that a single sample

TABLE 1

Mineral composition of mare milk[1]

Weeks postpartum	Number of observations[2]	Dry matter	Ash	Ca	P	Mg	K	Na	Cu	Zn
		%		*μg/g of fluid milk*						
1	4	12.0 ± 0.17	0.61 ± 0.03	1345 ± 66	943 ± 46	118 ± 10	664 ± 156	237 ± 48	0.85 ± 0.40	3.1 ± 0.67
2	11	11.5 ± 0.52	0.57 ± 0.05	1317 ± 130	866 ± 61	108 ± 10	665 ± 117	196 ± 80	0.69 ± 0.30	2.7 ± 0.46
3	14	10.8 ± 0.32	0.51 ± 0.04	1160 ± 116	742 ± 42	92 ± 5	547 ± 156	184 ± 46	0.42 ± 0.16	2.4 ± 0.82
4	13	10.5 ± 0.44	0.45 ± 0.04	1070 ± 138	659 ± 58	86 ± 8	469 ± 117	161 ± 69	0.55 ± 0.25	2.2 ± 0.54
5	14	10.3 ± 0.27	0.42 ± 0.04	919 ± 101	615 ± 38	74 ± 8	391 ± 117	184 ± 68	0.46 ± 0.24	1.8 ± 0.40
6	14	10.3 ± 0.42	0.41 ± 0.06	931 ± 132	593 ± 68	69 ± 7	391 ± 117	184 ± 68	0.41 ± 0.08	2.1 ± 0.43
7	13	10.2 ± 0.63	0.40 ± 0.04	896 ± 84	600 ± 55	63 ± 8	430 ± 156	161 ± 46	0.34 ± 0.10	2.0 ± 0.49
8	10	10.0 ± 0.47	0.38 ± 0.04	831 ± 107	574 ± 39	58 ± 8	469 ± 78	138 ± 23	0.29 ± 0.11	1.9 ± 0.30
9–11	7	10.2 ± 0.10	0.37 ± 0.01	878 ± 124	580 ± 29	56 ± 8	356 ± 62	180 ± 57	0.22 ± 0.05	1.9 ± 0.31
12–14	5	10.3 ± 0.19	0.36 ± 0.03	779 ± 78	550 ± 64	49 ± 5	413 ± 81	115 ± 0	0.12 ± 0.06	1.7 ± 0.56
15–17	5	10.2 ± 0.49	0.32 ± 0.01	700 ± 51	540 ± 42	43 ± 2	341 ± 103	115 ± 0	0.28 ± 0.07	1.8 ± 0.53

[1]Values are means ± SD. [2]Samples were obtained from five mares for the first 8 wk postpartum and from two mares from 9 to 17 wk postpartum. During the first week, samples were obtained on d 3, 6 and 7 from four mares.

TABLE 2

Comparison of reported values for mineral components of mare milk[1]

Breed	Reference	No. of mares	Week 4							Week 8							Week 16						
			Total solids	Ash	Ca	P	Mg	K	Na	Total solids	Ash	Ca	P	Mg	K	Na	Total solids	Ash	Ca	P	Mg	K	Na
Shetland pony	Linton (5)[2]	8	10.5	0.35	1265	1205				10.1	0.33	1188	1055				10.6	0.26	945	865			
Percheron	Holmes et al. (12)	4	10.0		1060	710	112	790		9.8		950	590		630	86	10.3		1020	630	90	640	
Mixed	Neseni et al. (2)[3]	15	10.5	0.45	847	580		624	112	10	0.39	791	540		502	97	10.0	0.30	485	467		303	75
Arabian & quarterhorse	Ullrey et al. (7)	10	11.3	0.46	1186	358	65	580	186	10.3	0.37	905	285	49	456	203	10.0	0.27	614	216	43	370	161
Dutch warmblood	Bouwman & van der Schee (13)	5	11.2	0.38	950	600				11.2	0.35	950	600				10.8	0.27	700	500			
Thoroughbred	This study	5	10.5	0.45	1070	659	86	469	161	10.0	0.38	831	574	58	469	138	10.2	0.32	700	540	43	341	115

[1]Total solids and ash are given as percent and minerals as $\mu g/g$ of fluid milk. [2]Linton sampled eight Shetland ponies and one Clydesdale mare. [3]Neseni et al. sampled "cold blooded" horses, Hannoverian and East Prussian "warm blooded" horses, Arabians and Shetland pony mares.

of mare milk cannot be said to be representative of lactation and that the stage of lactation must be specified in describing mare milk.

Previously reported values for total solids, ash and major minerals in mare milk at the end of the first, second and fourth months of lactation are compared with some of the results of our study in table 2. The composition of cow milk is influenced by the breed, age and nutrition of the dam, genetics, stage of lactation, season of year, temperature and other factors (6). Methods of sampling and analytical methods can also strongly influence results. However, with the exception of the low phosphorus concentration of the milk of Arabian and quarter horse mares reported by Ullrey et al. (7), our values are similar to those previously reported. In addition, our values for copper and zinc (table 1) are similar to values reported by Ullrey et al. (8).

There has been little effort to determine differences in composition of the milk of mares of different breeds since Linton's study in 1931 (11). He compared the content of ash and some organic constituents of the milk of 89 mares of 5 different British breeds and 53 crossbred mares. Linton noted only that the ash content of the milk of the heavy Clydesdale and Shire breeds tended to be lower than that of the light Thoroughbred and Hunter horses and Shetland ponies. The comparisons shown in table 2 also suggest little difference in the composition of milk of different breeds of horses. However, samples were obtained and analyzed by the various investigators under widely differing circumstances. Further studies are needed to define possible breed differences in the mineral composition of mare milk.

Results of our study indicate that mare milk contains adequate amounts of the major minerals for foal growth. Assuming that the minerals in mare milk are readily available to the foal, mare milk can provide all of the calcium, phosphorus, magnesium, sodium, potassium, zinc and copper needed by foals even in the absence of other nonmilk food resources. Table 3 shows the body mineral stores of the whole body of foals at birth (9) and at 4 months of age (10). The difference in body mineral composition of

TABLE 3

Contribution of mare milk to foal mineral nutrition[1]

Mineral	Foal body composition[1] At birth	Foal body composition[1] At 4 mo	Mineral accretion[2]	Mineral intake from mare milk[3]
			g	
Ca	950	2482	1532	1876
P	504	1207	703	1281
Mg	20	54	34	133
K	103	282	179	885
Na	99	211	112	322
Zn	2.2	4.4	2.2	4.2
Cu	0.3	0.6	0.3	0.6

[1]Foal body composition data from Meyer and Ahlswede (9) for newborn foals and Schryver et al. (10) for 4-mo-old foals. [2]Mineral accretion is the difference in body mineral composition between birth and 4 mo of age. [3]Mineral intake from mare milk is the accumulated grams of mineral for 120 d of lactation, assuming a mineral composition of milk similar to that found in this study and milk intakes by foals similar to that found by Oftedal et al. (1983).

foals at the two ages is mineral accretion that occurred during the 4-mo growth period. Intake of mare milk by the foal has been shown to be about 16 kg/d for the first 5 wk postpartum and about 18 kg/d thereafter (4). Intake of milk at similar rates and having a composition similar to that found in the present study provides major minerals in excess of the amount accreted into the body of the foal from birth to 4 mo. For example, the total calcium intake by the foal from mare milk alone for 120 d of lactation is 20% greater than the calcium accreted into the foal's body for the equivalent period. Similarly, phosphorus, zinc and copper intake from milk is about 50% greater, and sodium, magnesium and potassium intake is 65–80% greater than the accreted minerals in the foal's body. Foals generally obtain minerals from other feed sources during the first 4 mo of life. However, the data in table 3 suggest that mare milk alone is an adequate source of the major minerals required by the foal.

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