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The B-vitamin content of baboon (*Papio cynocephalus*) milk

BY D. H. BUSS*

Southwest Foundation for Research and Education, San Antonio, Texas 78284, USA

AND J. E. FORD AND K. J. SCOTT

National Institute for Research in Dairying, Shinfield, Reading RG2 9AT

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1. The B-vitamins in milk from baboons (*Papio cynocephalus*) at various stages of lactation were measured microbiologically.

2. Mature milk contained, on average (μg/ml): thiamin 0·18, riboflavin 0·74, nicotinic acid 3·2, folate 0·03, vitamin B_6 0·70, vitamin B_{12} 0·002, pantothenic acid 2·63, biotin 0·0065.

3. Colostrum contained much less vitamin B_6 and pantothenic acid than mature milk; otherwise, there were only slight changes in composition as lactation progressed. Neither these changes, nor the absolute values, resembled those for human or cow's milk.

4. The average daily secretion of B-vitamins in milk represented less than 10 % of the mother's dietary intake; that of folate was less than 0·5 % of the mother's dietary intake.

5. Baboon milk was calculated to provide infants with approximately the following quantities of B-vitamins (/d): thiamin 0·06 mg, riboflavin 0·25 mg, nicotinic acid 1·1 mg, folate 10 μg, vitamin B_6 0·25 mg, vitamin B_{12} 0·7 μg, pantothenic acid 0·9 mg, biotin 2·2 μg.

There are many parallels between lactation in humans and in non-human primates. For example, human milk contains less protein, fat and minerals, but more lactose, than milk from nearly all mammals except other primates (Jenness & Sloan, 1970). The yield of milk is also lower in relation to body size in women than in all other mammals studied except for baboons (Linzell, 1972). There are morphological and other physiological similarities between these species too, and this led the World Health Organization to recommend that priority should be given to research on lactation in non-human primates as well as in women (WHO, 1965).

Although a considerable amount of such work has now been done (see Buss, 1971), there has been no study of the vitamin content of milk from any non-human primate. We therefore undertook an investigation of the B-vitamins in baboon milk at various stages of lactation, and report the results in this paper.

EXPERIMENTAL

Animals

All twenty-one baboons included in this study were classified as *Papio cynocephalus*. They were fed only on standard biscuits (SFRE 'experimental ration') whose composition and vitamin content has been described (Hummer, 1970). Water was also continuously available. Each mother gave birth naturally and was raising her infant successfully.

Milk samples

Milk was obtained after sedation and oxytocin (Armour-Baldwin Laboratories, Omaha, Nebraska) administration (Buss, 1968). Part of each sample (4 ml where possible) was

* Present address: 5 Howard Close, Fleet, Hampshire GU13 9ER.

added to the appropriate pool and frozen to −30° immediately; a smaller part (up to 2 ml) of most samples was also taken for folate assay and mixed with half its volume of ascorbic acid–phosphate buffer (Ford, 1967) before being added to a separate pool and frozen. It was necessary to prepare pooled samples because of the difficulty of obtaining much more than approximately 5 ml milk from baboons even at the height of lactation (Buss & Kriewaldt, 1968), while analysis of the eight B-vitamins required about 20 ml.

Milk was collected in both 1970 and 1971. In 1971, twenty-five samples were taken during March and April from thirteen animals who gave birth between November 1970 and April 1971, and they were pooled according to the stage of lactation within the somewhat arbitrary limits of 1 to 2 d (colostrum), 3 d to 2 weeks (early lactation), 2 weeks to 3 months (mid lactation) and more than 3 months (late lactation). In 1970, thirty-five samples were taken mainly during August and September from six animals who gave birth between April and September; one pool of colostrum and another of early milk were made (and included samples from three more baboons in October and December), while the remainder of the milk was pooled according to animal. This sampling scheme was largely imposed by other circumstances, but should serve to indicate differences in composition both according to length of lactation and between animals. Seasonal differences were not expected from animals given an unvarying diet and having no marked breeding season (Kriewaldt & Hendrickx, 1968).

Analysis

The analyses were performed in 1971, and because the samples had been maintained in the dark at −30° it was assumed that there was little or no loss of vitamins. Riboflavin, nicotinic acid, pantothenic acid and biotin were assayed by standard microbiological procedures (Ford, Gregory, Porter & Thompson, 1953; Chapman, Ford, Kon, Thompson, Rowland, Crossley & Rothwell, 1957). Folate activity was assayed with *Lactobacillus casei*, by an adaptation of the procedure recommended by Herbert (1961) for the assay of folate in blood serum (Ford, 1967). Vitamin B_{12} was assayed with *Lactobacillus leichmannii* as described by Gregory (1954), and thiamin with *Lactobacillus fermenti*; the test medium was that of Banhidi (1958), and the milk samples (1 ml) were extracted by heating for 30 min at 100° with 20 ml 0·033 M-sulphuric acid. Vitamin B_6 was assayed with *Kloeckera brevis* as described by Barton-Wright (1963), except that the test samples were extracted with 0·055 M-hydrochloric acid as recommended by Gregory (1959).

RESULTS AND DISCUSSION

The concentration of the eight B-vitamins in each sample of baboon milk is shown in Table 1. As with milk from other species there were considerable variations between the values, with some samples containing twice as much of certain vitamins as others at similar stages of lactation. It is, however, impossible to provide standard errors for these results because the samples were too small for replicate analyses to be done.

Despite this, some trends could be discerned in the vitamin content of the milk as lactation progressed. In particular, baboon colostrum contained only 0·10 of the vitamin B_6 and 0·20 of the pantothenic acid of later milk. Cow's colostrum also contains somewhat less of these vitamins than does transitional milk, but then there is a decrease in later samples (Hartman & Dryden, 1965) which was not observed in the baboon. The thiamin, riboflavin, folate and vitamin B_{12} contents of baboon colostrum were of the same order as in the other samples, although a slight increase in thiamin could be discerned as lactation progressed and transitional milk was perhaps highest in riboflavin;

Table 1. *Vitamin content of baboon (Papio cynocephalus) milk (μg/ml)*

Samples pooled according to lactation stage

Stage of lactation	No. of animals contributing to each pool	Thiamin*	Riboflavin	Nicotinic acid	Folate	Vitamin B_6*	Vitamin B_{12}	Pantothenic acid*	Biotin
Colostrum (a)	5	0·09	0·50	2·00	0·022	0·05	0·0015	0·44	0·004
(b)	2	0·15	0·72	3·98	—	0·07	—	—	
Early lactation (a)	6	0·15	1·00	3·53	0·028	0·47	0·0011	2·06	0·006
(b)	3	0·08	0·78	3·85	0·044	0·48	0·0007	2·32	0·004
Mid lactation (a)	7	0·16	0·86	3·13	0·026	0·82	0·0021	3·48	0·004
(b)	7	0·16	0·68	2·95		0·77	0·0017	3·00	—
Late lactation	5	0·21	0·80	2·63	0·038	0·74	0·0052	2·40	—

Samples pooled according to animal

Animal	Stage of lactation	No. of samples from each animal	Thiamin*	Riboflavin	Nicotinic acid	Folate	Vitamin B_6*	Vitamin B_{12}	Pantothenic acid*	Biotin
A	Day 14	1	0·21	0·78	4·25	0·022	0·73	0·0005	2·40	0·012
B	Days 16–23	2	0·23	0·64	3·38	0·030	0·30	0·0024	1·96	—
C	Days 21–47	5	0·11	0·82	3·20	0·040	0·54	0·0015	2·40	0·006
D	Days 43–92	7	0·15	0·64	3·40	0·024	0·82	0·0011	2·56	0·006
E	Days 108–143	6	0·24	0·70	3·48	0·032	0·73	0·0017	2·36	0·008

* Expressed as thiamin hydrochloride, pyridoxine hydrochloride and calcium D-pantothenate respectively.

in contrast, human colostrum is comparatively rich in riboflavin and vitamin B_{12} but poor in thiamin and folate (Gregory, 1975), while cow's colostrum is rich in all four of these vitamins (Hartman & Dryden, 1965). Any differences between the nicotinic acid and biotin contents of colostrum and milk in baboons or in the other species appear to be of little significance.

From these results, the average vitamin content of mature milk, i.e. of samples taken 14 d or more postpartum, is (μg/ml): thiamin 0·18, riboflavin 0·74, nicotinic acid 3·2, folate 0·03, vitamin B_6 0·70, vitamin B_{12} 0·002, pantothenic acid 2·63, biotin 0·0065. Almost identical values were obtained whether the mean or a weighted mean was taken.

In Table 2 the average vitamin content of mature baboon milk is compared with that of mature human and cow's milk. Again baboon milk was not markedly similar to human milk: it was substantially richer in vitamin B_6 and vitamin B_{12}, and also contained more riboflavin, nicotinic acid and pantothenic acid, and less folate and biotin than did milk from humans. Neither was baboon milk similar to cow's milk. These comparisons should, however, be taken as an approximation only, for the secretion of B-vitamins into human milk, and therefore almost certainly into baboon milk, varies within considerable limits according to the quantities in the mother's diet (Kon & Mawson, 1950).

Knowing that baboons secrete about 340 ml milk/d (Buss & Voss, 1971), it was possible to calculate the average daily 'loss' of B-vitamins from mother to infant. The daily intake of B-vitamins by the mother could also be calculated, for the vitamin content of the standard ration is known (Hummer, 1970), and lactating baboons eat 376 g/d on average

Table 2. *Comparison of B-vitamin content (μg/ml) of baboon (Papio cynocephalus) milk with human and cow's milk*

	Baboon	Human*	Cow*
Thiamin	0·18	0·16	0·44
Riboflavin	0·74	0·36	1·75
Nicotinic acid	3·2	1·47	0·94
Folate	0·03	0·05	0·05
Vitamin B_6	0·70	0·10	0·64
Vitamin B_{12}	0·002	0·0003	0·0043
Pantothenic acid	2·63	1·84	3·46
Biotin	0·0065	0·022	0·031

* From Hartman & Dryden (1965), except for the values for folate, which are taken from Ford & Scott (1968).

Table 3. *Comparison of the approximate daily intake and milk output of B-vitamins by lactating baboons (Papio cynocephalus)*

	Food concentration (/kg)	Intake (/d)	Milk concen-tration (/l)	Output (/d)	Proportion in the milk
Thiamin (mg)	8·3	3·1	0·18	0·06	0·02
Riboflavin (mg)	10·0	3·8	0·74	0·25	0·07
Nicotinic acid (mg)	102·9	38·7	3·2	1·09	0·03
Folic acid (mg)	6·3	2·4	0·03	0·01	0·004
Vitamin B_6 (mg)	20·2	7·6	0·70	0·24	0·03
Vitamin B_{12} (μg)	21·8	8·2	2·0	0·68	0·08
Pantothenic acid (mg)	69·1	26·0	2·63	0·89	0·03
Biotin (μg)	230	86·5	6·5	2·2	0·03

(Buss & Voss, 1971). These values are compared in Table 3, which shows that less than 0·5 % of the dietary folate passed into the milk and that even the heaviest losses (of riboflavin and vitamin B_{12}) represented only 7 and 8 % of the dietary intake respectively. This finding compares with a daily loss of 6 % of the dietary nitrogen and 17 % of the energy in the diet, calculated in a similar manner from the gross composition of baboon milk (Buss, 1968). It must, however, be remembered that some of the B-vitamins (particularly folate and vitamin B_{12}) may not be completely absorbed, so the quantities in milk will represent a somewhat greater proportion of the amounts actually available to the mother.

Similar calculations can also be made for human lactation, although we are only aware of one direct comparison between intake and output (Kon & Mawson, 1950); this woman lost, on average, the following (% dietary intake): thiamin 7, riboflavin 8, nitrogen 8, energy 14. These values are remarkably similar to those for baboon lactation, and their low values indicate in yet another way how low the metabolic stress of lactation is in primates compared with other mammals (cf. Payne & Wheeler, 1968).

The values obtained in this study may also be used to estimate the vitamin requirements of baboon infants, and therefore to improve the hand-rearing of this species. On the assumption that the infant's needs for vitamins are of the same order as the amounts provided by the mother's milk, they would be (/d): thiamin 0·06 mg, riboflavin 0·25 mg, nicotinic acid 1·1 mg, folate 10 μg, vitamin B_6 0·25 mg, vitamin B_{12} 0·7 μg, pantothenic acid 0·9 mg, biotin 2·2 μg. These may be compared with the daily intakes recommended by the (US) National Academy of Sciences (1974) and the United Nations (FAO, 1974) for human infants, i.e.: thiamin 0·3–0·5 mg, riboflavin 0·5–0·6 mg, nicotinic acid equivalents 5–8 mg, folate 50–60 μg, vitamin B_6 0·3–0·4 mg, vitamin B_{12} 0·3 μg.

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