The milk of the African elephant

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1. Analyses have been made of milk collected from thirty wild African elephants immediately after they were shot.

2. The milk contained an average of 5·1 % protein, 9·3 % fat and 3·6 % lactose. The concentration of lactose decreased and the concentration of protein and fat increased with advancing lactation. Inorganic constituents were present in approximately the same proportions as in bovine milk.

3. The contribution of capric acid to the total fatty acids, previously shown to be extremely high, increased with advancing lactation.

4. The significance of these findings to the preparation of a milk for rearing young elephants by hand is discussed.

Overpopulation of some East African national parks with elephants has recently made it necessary to reduce the numbers by controlled shooting. The reasons for this and the methods used have been described by Laws & Parker (1968). As part of a concurrent research programme, a study of the composition of elephant milk was initiated. This paper records the results.

The milk of the African elephant (*Loxodonta africana*) is of interest for several reasons. Firstly, considerable difficulty has been associated with the artificial rearing of elephant calves from birth in captivity. The difficulty has often been attributed to a lack of knowledge of the natural composition of the milk of the elephant, and hence to the use of a milk substitute of grossly unnatural composition.

Secondly, the elephant is a mammal in many ways comparable with man. It has a potential life span in the wild of 60 years, which is close to man's three score and ten. Both species grow slowly, the elephant taking even longer than man to double its birth weight, whilst puberty occurs at a similar age. Anatomical similarities also exist, the female elephant, like woman, possessing pectoral mammary glands.

Thirdly, the average weight of the elephant at birth is 120 kg (Laws & Parker, 1968), and it is therefore the largest mammal born on land. Bunge (1898) originally drew attention to a relationship between the composition of milk and the size and rate of growth of the infant mammal, and Blaxter (1961) and McCance & Widdowson (1964) enlarged upon this relationship. There appears to be a tendency for large terrestrial animals to produce less concentrated milks than small ones, for on the whole their rate of growth during suckling is slower. A knowledge of just how the milk of the elephant fits into these generalizations has been limited by the paucity of values for its composition.

Some observations on the milk of captive elephants are available but no mention is made of whether these animals belonged to the African or Indian genus. Krauze &

Legatowa (1949) reported the percentage of fat to be 13·2, and Anselmi & Calo (1949), whilst not noting the fat specifically, gave values for total solids and solids-not-fat of 13·6 and 10·7% respectively, which would indicate only 2·9% of fat. An earlier study by Nottbohm (1939), again on a single elephant of unstated origin, gave 15·1% fat. The values reported for the percentage of lactose have varied from 2·4 to 4·1, and the only value available for protein (Nottbohm, 1939) is one of 4·9%. Markuze (1939) analysed the milk of an unspecified elephant for vitamins A, D, B_1, B_2 and C, and found that the concentrations of vitamins A and D were lower, and those of vitamins B_1 and C higher than their concentrations in cow's milk.

The mean composition of the milk of the Indian elephant (*Elephas maximus*) was given by Simon (1959) as fat 11·6%, protein 4·9%, lactose 4·8% and ash 0·66%. This is similar to the results summarized by Reuther (1969) except for fat, which in the 1st year of lactation had a mean percentage of 6·7.

In the present study an opportunity presented itself to investigate the milk of over thirty wild African elephants from two populations in East Africa. The approximate age and stage of lactation of these females was known, and we have therefore determined the concentrations of the major constituents and minerals and examined the changes as lactation proceeded, and as the females get older. A description of the fatty acid composition of the fat of these milks has already been published (McCullagh, Lincoln & Southgate, 1969).

EXPERIMENTAL

Field methods

Shortly after the elephants had been shot the skin and teats of the mammary glands were washed with water and the milk was expressed manually into jars with mouths wide enough to collect the spray of milk that issued from the multiple teats and ducts. The milk was transferred to 25 ml 'universal' screw-cap containers and stored in cooled

Table 1. *Distribution of samples of elephant's milk in terms of age of cow and stage of lactation*

Sample no.	Age of cow (years)	Stage of lactation (months)	Sample no.	Age of cow (years)	Stage of lactation (months)
1	23	—	16	23	10
2	27	—	17	38	12
3	31	—	18	26	12
4	40	—	19	26	12
5	33	—	20	39	12
6	29	—	21	34	12
7	36	2	22	36	16
8	19	3	23	47	18
9	33	3	24	45	18
10	25	3	25	35	18
11	31	6	26	49	24
12	20	6	27	30	28
13	36	9	28	26	33
14	34	9	29	22	33
15	20	9	30	32	36

vacuum flasks during the dissection of the carcasses. The samples were transferred to a deep-freeze within a few hours, and stored at −20° until required for analysis.

Elephant cow and calf herds tend to consist of family units (Buss, 1961; Laws & Parker, 1968) and, therefore, a study of the ages of the calves in a herd gave an indication of the stage of lactation of their mothers. The ages of both cows and calves were determined in the field by Dr R. M. Laws and Mr I. S. C. Parker, using a recently developed method based on the state of eruption and wear of the molar teeth (Laws 1966). The animals whose milks were selected for analysis were those in which the stage of lactation could be determined with some confidence. Where it was possible, the stage of lactation was checked from the scar left in the uterus of the cow after parturition. This scar remains visible for several years, and the time since calving can be estimated from the degree of involution and healing (Laws, 1967). Details of the milk samples collected are shown in Table 1.

Laboratory methods

The milk samples were transported frozen to Cambridge. They were thawed in the laboratory and subsampled at the same time for all the analyses, to avoid constant freezing and thawing. No homogenization was necessary but the samples were mixed carefully before subsampling.

A 5 ml subsample was pipetted into a crucible, weighed and its density calculated. The percentage of water was calculated from its weight before and after drying at 100° to constant weight. The sample was then ashed at 450°, reweighed, the ash dissolved in 0·1 N-HCl and the extract used for the determination of inorganic constituents.

A 2 ml subsample was used for the determination of nitrogen by the micro-Kjeldahl method with sodium selenite as the catalyst. Protein was calculated by multiplying the total N by 6·38. Fat was determined on duplicate 2 ml subsamples by a modification of von Lieberman & Szekely's method, described by Southgate & Barrett (1966). Lactose was measured by the anthrone method after deproteinization of further 2 ml portions (Slater, 1961).

Sodium and potassium in the ash extracts were determined by flame emission and calcium and magnesium by atomic absorption in a Pye-Unicam 'SP90' spectrophotometer. Phosphorus was determined colorimetrically by the phosphomolybdic acid reaction (Fiske & SubbaRow, 1925). Chloride was measured by automated titration against silver ions, in a Buchler–Cotlove chloridometer.

RESULTS

The milk of these wild elephants was a thin, rather watery fluid with a mild but distinctive smell and a slightly bitter taste. It had a tendency to cling to glassware. The fresh milk did not form a cream line on standing, but freezing and thawing produced some separation. The size of the fat globules in this milk was only half that of the globules of bovine milk. The mean density of the samples was 1·00 g/ml at 20°.

The results of the chemical analyses are contained in Table 2. The coefficient of variation expresses the degree of variation amongst the milks and in most instances was fairly high. One reason for this was probably the small size of the sample. It was rarely possible to collect more than 25 ml from the glands after death and this may not have been truly representative of the full day's milk secretion. The variation in the concentration of the major constituents was equally high when expressed in terms of fat-free milk.

Table 2. *Mean composition per* 100 *ml of the milk of thirty wild African elephants*

Constituent	Mean	Standard deviation	Coefficient of variation [(SD/mean) × 100]
Water	79·1 g	5·6	7·1
Fat	9·3 g	3·7	39·8
Solids-not-fat	10·8 g	3·2	29·6
Protein	5·1 g	1·1	21·5
Lactose	3·7 g	1·6	43·3
Ash	730 mg	27·0	3·7
Calcium	132 mg	42·5	32·1
Magnesium	12 mg	3·5	28·1
Phosphorus	84 mg	21·1	25·2
Potassium	188 mg	30·7	16·4
Sodium	72 mg	21·9	30·4
Chloride	150 mg	40·0	26·7

Table 3. *Coefficients for the linear regression of constituent concentration on age of cow and stage of lactation*

	Age of cow			Stage of lactation		
Constituent	Coefficient b_1	Standard error	Significance	Coefficient b_2	Standard error	Significance
Water	+0·002	0·072	NS	−0·330	0·060	***
Fat	+0·054	0·071	NS	+0·290	0·060	***
Solids-not-fat	−0·040	0·067	NS	+0·022	0·053	NS
Protein	−0·028	0·022	NS	+0·089	0·018	***
Lactose	−0·056	0·035	NS	−0·090	0·030	**
Ash	+0·007	0·008	NS	+0·007	0·007	NS
Calcium	−1·060	1·790	NS	+0·865	1·443	NS
Magnesium	−1·162	0·116	NS	+0·151	0·093	NS
Phosphorus	−0·510	0·651	NS	+1·300	0·520	*
Potassium	+1·290	0·900	NS	+0·804	0·722	NS
Sodium	−0·525	0·930	NS	−0·468	0·749	NS
Chlorine	−0·167	1·972	NS	−2·470	2·080	NS

Significance: NS not significant. * $P = < 0·05$. ** $P = < 0·01$. *** $P = < 0·001$.

We investigated two other possible sources of variation; the age of the cow, which to a large extent represented the number of previous lactations, and the age of the calf, which indicated the length of time for which the cow had been lactating. Denoting the age of the cow as x_1 and the age of the calf as x_2, the dependence of the concentration of each constituent (Y) on these two factors was investigated by calculating the bivariate regression coefficients (b_1 and b_2) in the equation

$$Y = \mu + b_1 x_1 + b_2 x_2 + \text{error}.$$

It can be seen from Table 1 that there were no grounds for believing that the number and stage of lactation were not independent of each other, but to be sure of this, interaction between them was tested by fitting a second model to the values:

$$Y = \mu + b_1 x_1 + b_2 x_2 + b_3 x_1 x_2 + \text{error}.$$

In no instance was there found to be a value of b_3 which was significant, proving the independence of the two variables.

Values of b_1 and b_2, together with their standard errors are given in Table 3. The age of the mother, and hence the number of previous lactations, had no significant

Table 4. *Composition of the milk of seven species*

(per 100 g)

	Elephant*	Man†	Ox†	Horse‡	Pig‡	Rhinoceros§	Giraffe‖	Rabbit¶
Total solids (g)	20·1	12·4	12·7	10·1	21·0	8·8	23·8	31·1
Fat (g)	9·3	3·8	3·7	1·6	8·5	0·5	12·5	16·7
Protein (g)	5·1	1·2	3·3	2·2	5·8	1·5	5·8	10·4
Lactose (g)	3·7	7·0	4·8	6·0	4·8	6·1	3·4	2·0
Energy (kcal)	121	68	67	48	122	35	154	206
Ash (m)	730	210	720	400	940	340	900	2000
Calcium (mg)	130	33	125	100	270	60	154	500
Magnesium (mg)	10	4	12	10	—	—	—	—
Phosphorus (mg)	80	15	96	60	160	40	104	340
Potassium (mg)	190	55	138	70	—	90	100	160
Sodium (mg)	70	15	58	—	—	40	100	120
Chloride (mg)	150	43	103	20	90	80	134	—

* Present experiment. † Macy, Kelly & Sloan (1953).
‡ Ling, Kon & Porter (1961). § Gregory, Rowland, Thompson & Kon (1965).
‖ Creed (1960) ¶ Evans (1959).

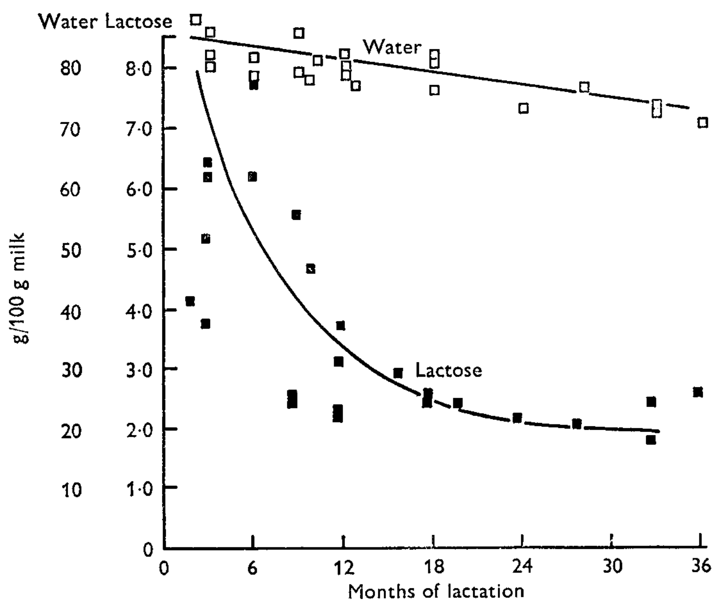

Fig. 1. Changes in the percentage of water and lactose in elephant's milk during lactation. Closed squares, lactose; open squares, water.

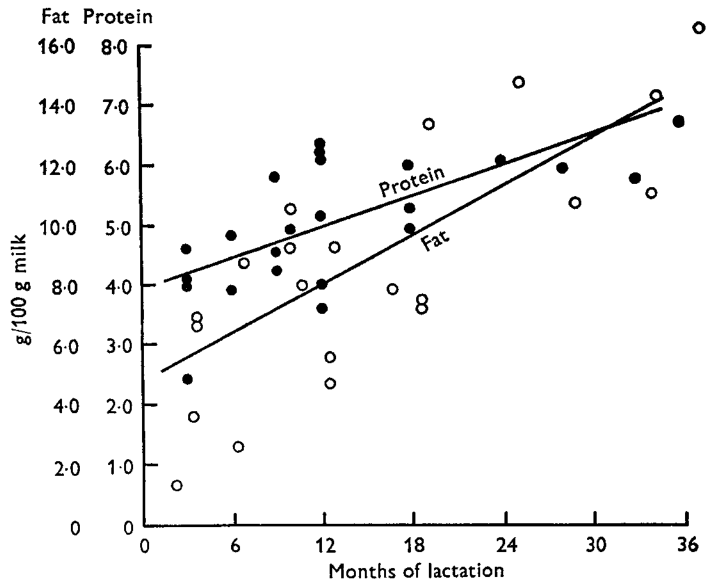

Fig. 2. Changes in the percentage of protein and fat in elephant's milk during lactation. Closed circles, protein; open circles, fat.

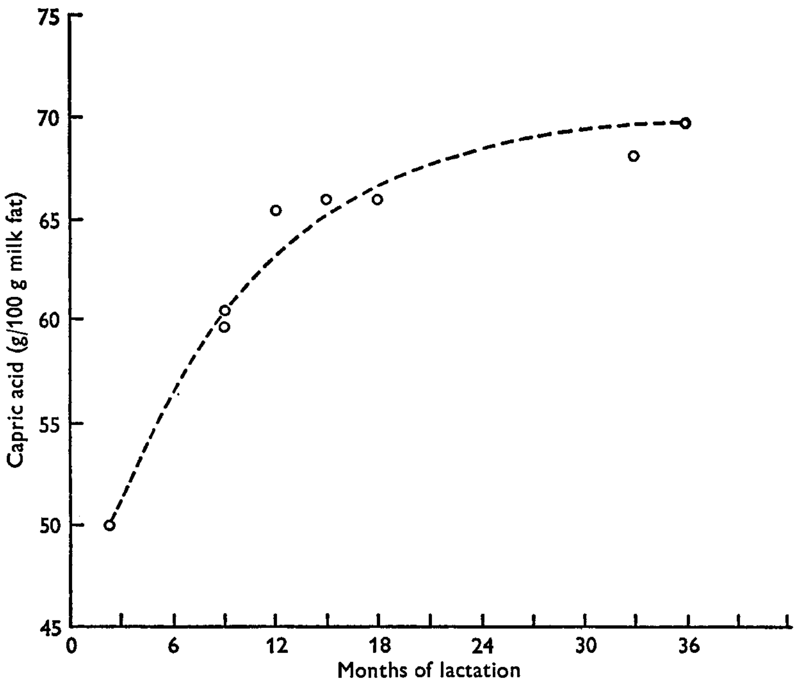

Fig. 3. Relationship between the percentage of capric acid in the milk fat of elephants and the stage of lactation.

effect on milk composition. The stage of lactation, on the other hand was an important source of variation in the concentration of protein, fat, lactose and phosphorus. From Table 3 it will be seen that as the lactation proceeded, the concentration of protein and fat rose whilst lactose fell. The water content of milk fell, indicating an increase throughout the lactation in dry-matter content, but this increase was mainly due to the increase in fat, for the regression of solids-not-fat on stage of lactation was not significant. These changes are depicted graphically in Figs. 1 and 2, where the mean regression lines have been drawn through the scatter of points.

The mineral content of the milk of these elephants is given in Tables 2 and 4. It will be seen that the minerals listed were present in approximately similar proportions to those in bovine milk, although there was slightly more potassium in elephant's milk. Phosphorus was the only mineral to be affected by the stage of lactation, increasing steadily as lactation proceeded.

In an earlier publication McCullagh *et al.* (1969) reported the unusual nature of elephant milk fat. In addition to the small size of the fat globules, the fatty acids of the milk glycerides were found to consist of 60–70% capric acid (C10:0), 13–22% lauric acid (C12:0), and only very small amounts of longer-chain fatty acids. We thought it of interest to investigate the relation between the amount of capric acid in the milk fat and the stage of lactation. Fig. 3 reports these results. It appears that the block to the synthesis of fatty acids of higher chain length, however it is caused, became more severe as the lactation advanced.

DISCUSSION

Elephant's milk, in common with the milk of the rabbit, had previously been regarded as unusual owing to its high fat content in relation to that of other terrestrial mammals. Our values for the percentage of fat in wild elephant's milk are not as high as those reported by Nottbohm (1939) or Krauze & Legatowa (1949) in milk from captive animals. As mentioned earlier, they obtained values of 15·1 and 13·2% respectively. Whilst we certainly had one or two milk samples in this range, the majority of our samples were lower, averaging 9·3%. This brings the fat percentage more into line with that of the pig (see Table 4).

It should therefore not be necessary, as has previously been done, to insist on a milk substitute with a very high fat content for hand rearing of young elephants. Bolwig, Hill & Philpott (1965) reported the successful rearing of an elephant calf on a dried milk powder made up to double strength and supplemented with sufficient butter to bring the fat content to 17%. This seems excessive in the light of our findings and it is significant that oxytetracycline and kaolin had to be administered to control enteritis. Others have found full-cream cow's milk highly unsatisfactory (Sleat, 1962). Bellinge & Woodley (1964) and Taylor (1955) considered that the digestion of fat in the elephant calf was delicate and specific. One reason for this could be the unusual nature of elephant milk fat, already mentioned. The highly unusual nature of the fatty acids in the milk is reflected in the composition of the depot triglycerides of the suckling elephant calf, which are rich in capric, lauric and myristic acids (Duncan & Garton, 1968). Capric acid is not present in the adipose tissue of the adult elephant, but occurs at a concentration of almost 6% in the adipose tissue of the elephant calf. Interestingly, capric acid is also found as a major component of rabbit milk fat (Smith, Watts & Dils, 1968), although still at less than half its concentration in elephant milk fat. Differences in the nature of protein in the milk of elephants and cows may also be present but we have not investigated them.

Nevertheless, the pronounced difference between bovine and elephant milk fat makes it quite likely that the young elephant is intolerant of bovine milk fat. It is difficult to overcome this problem when rearing young elephants by hand, for fats containing capric acid in large amounts are uncommon. Coconut oil would appear to be one of the most suitable on chemical grounds, for although it contains only 4·5% of capric acid (C 10:0), it has 51% of lauric acid (C 12:0) (Hilditch & Williams, 1964).

The composition of elephant milk is compared in Table 4 with that of man and some other mammalian species. It will be seen that elephant's milk is more akin to the milk of the sow, in concentrations of fat, protein and lactose, than to human milk from which it differs considerably. Neither is there a similarity between elephant's and human milk in mineral composition. Here the elephant's milk is more akin to bovine milk. Neither are the changes with lactation typical of human milk. In man, protein levels fall and lactose tends to rise as lactation proceeds (Hytten, 1954). It therefore seems that the similarity in the rates of growth of elephants and children has no significance in relation to the composition of the milk.

Comparisons with other large wild African herbivores also appear in Table 4. There seems to be no consistent relationship between body size and milk composition. Although all these large animals secrete a less concentrated milk than that of the rabbit or the rat, the elephant's milk is more than twice as concentrated as that of the rhinoceros. The difference is mainly due to the almost complete absence of fat in the milk of the rhinoceros, but it also contains a low percentage of protein; it resembles more closely the milk of the mare and the ass. This suggests that genetic factors are more important than body size and environment in determining milk composition, for the rhinoceros and the horse belong to the same phylogenetic order, the Perissodactyla. The similarity between the milks of the elephant and the sow adds weight to the suggestion of Duncan & Garton (1968), that there may be a closer relationship between pigs and elephants than is implied by their classification in separate orders.

The milk of the giraffe is also similar to that of the elephant, providing four times as much energy per 100 ml as the milk of the rhinoceros. Preliminary studies in this laboratory show that the milk of the hippopotamus is even richer in fat and protein than that of the giraffe and elephant, and provides almost twice the energy of elephant milk per unit weight.

Variations in the composition of the milk during lactation have been noted in the dairy cow (Waite, White & Robertson, 1956) but these are not very large. Lactose reaches a peak in the dairy cow at about the 7th week of lactation and then drops slowly, declining more rapidly in late lactation. In the elephant cow the fall is rapid at first, becoming slower in late lactation.

These changes may reflect an inability of the elephant cow to continue secreting lactose under the prolonged stress of lactation, or it may reflect an adaptation to the changing digestion of the calf. It is known that the lactase present in the intestinal mucosa of young animals declines rapidly with age (Blaxter, 1961; Cook, 1967). Presumably there are changes during the lactation in gland function or changes in the level of circulating glucose, or in both. Rook & Witter (1968) have shown that, in undernutrition in the sow, both total yield and lactose concentration are depressed, and it may be that as lactation advances in the elephant the nutritional state of the mother deteriorates. We were not able to measure milk yield in these elephants, so this suggestion remains unconfirmed.

This work is part of a wider programme of research on elephants initiated by Dr R. M. Laws. We would like to thank him and Professor R. A. McCance for their encouragement and support. We also thank the Trustees of Uganda and Kenya Parks, Wildlife Services Ltd of Nairobi, and in particular Mr Ian Parker whose co-operation made the investigation possible. Dr R. C. Campbell and the ARC Statistics Unit, Cambridge, gave considerable assistance with the computation of results. The study was supported by The Royal Society and the Medical Research Council.

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