Mineral Content of Brands of Milk for Infant Feeding

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Summary

The amounts of sodium, potassium, phosphorus, and nitrogen in several brands of milk used for infant feeding have been measured, and the concentrations of these substances in the reconstituted milks calculated. The known variation in the electrolyte content of cows' milk and the addition of minerals in the manufacture of many types of milk foods may account for the variation in the content of these substances, but the addition of neutralized whey in the manufacture of Trufood Formula 4 increased the concentration of sodium to a level twice that found in undiluted cows' milk. We think that details of all mineral additions to milks used for infant feeding should be made readily available and that the mineral content of the powders or liquids should be printed on the containers and expressed both in mg/100 g and mEq/kg. Milks reconstituted to a composition close to that of cows' milk present large osmotic loads to the kidneys, and may endanger water balance in some circumstances. This risk can be reduced by a greater dilution with water.

Introduction

Minerals are added to cows' milk in the course of manufacture of many preparations used for infant feeding. They are added only when necessary and serve to adjust the pH or physical state in the process of making milk sterile, easy to reconstitute, and stable in composition. So far as we know sodium carbonate or bicarbonate are used in making some roller-dried and spray-dried milks, and a sodium phosphate or citrate is used in the manufacture of evaporated (unsweetened condensed) milk. A greater increase in mineral content is involved when whey, neutralized with sodium bicarbonate, is added.

Since we did not know what effect these mineral additions might have on the final composition of the milks, we decided to analyse several brands of milk for their content of sodium, potassium, calcium, and phosphorus. The nitrogen was also estimated as a measure of the contribution made by cows' milk to the final product.

Materials and Methods

The analyses were made on one to three packages of each brand obtained from retail shops. No attempt was made to estimate the variation within the brand except in the case of Trufood Formula 4, where packets from three different batches were analysed.

A weighed sample of milk was dried at 95°C and ashed at 475°C for 18-24 hours. The ash was dissolved in 10% hydrochloric acid and made up to 100 ml. Sodium, potassium, and calcium were measured by atomic emission spectrophotometry. Phosphorus was measured by the method of Gomorri (1942). Analyses were performed in duplicate or triplicate, and repeated.

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The coefficient of variation for all analyses was less than 2.5%. Nitrogen was estimated by the standard micro-Kjeldahl method using a selenium catalyst.

Calculations

The calculated urine osmolality resulting from feeding different milks was based on the results of the analyses and the following assumptions.

WATER BALANCE

Milk	87.5% water (Macey <i>et al.</i> , 1953)
Stool water 5 ml/kg/day	20 ml/day (Edelman and Barnet, 1960)
Water absorbed ..	(dietary water - stool water) ml/day
Water of metabolism ..	8 ml/100 ml milk (Ziegler and Fomon, 1971)
Insensible water loss ..	0.8-1.0 l./m ² /day (Heeley and Talbot, 1955)
Daily weight gain ..	30 g/day
New body water ..	(0.7 × body weight in g) ml/day (Widdowson and Dickerson, 1961)
Urinary water	(water absorbed + water of metabolism) - (insensible water loss + new body water) ml/day.

RENAL SOLUTE LOAD

Absorbed protein, Na⁺ and K⁺/day, (intake × 0.9)/day (Slater, 1961)
N₂ content of 4.0 kg infant, 19 g/kg (Widdowson and Dickerson, 1961)
Protein content (N₂ content × 6.25) g/kg
Protein content of new body substance (30 g), 3.5 g/day
(This value is consistent with measured retentions of nitrogen (Fomon and May, 1958))

$$\begin{aligned} \text{Urinary urea} &= \frac{2.14 (\text{absorbed protein} - \text{new body protein})}{6.25} \text{ g/day} \\ &= \frac{\text{Urinary urea g/24 hr}}{0.06} \text{ mOsm/day} \end{aligned}$$

Extracellular, fluid, intracellular fluid = (body water × 0.5) (Widdowson and Dickerson, 1961)

New extracellular fluid Na⁺, new intracellular fluid K⁺ = 1.4 mEq/day
Urinary Na⁺ (absorbed Na⁺ - new extracellular fluid Na⁺) mEq/day
Urinary K⁺ = (absorbed K⁺ - new intracellular fluid K⁺) mEq/day
Total urine solutes (urine urea/mOsm/day) × 2 (urinary Na⁺ × urinary K⁺) mOsm/day.

The urine solutes equation has been tested by comparing the measured urinary osmolality with the osmolality calculated from the measured concentration of urea, sodium, potassium, and ammonia. The above equation appears to underestimate osmolality slightly, and a better fit is obtained by including (2 × NH₃ mEq/day).

Results

The results of analyses for nitrogen, sodium, potassium, calcium, and phosphorus in the milk powders and evaporated milks are given in table I. Full Cream Cow & Gate, Ostermilk No. 2, Golden Ostermilk, and National Dried Milk are all full cream milk powders. They have a similar protein concentration but the mineral concentrations are more variable; this may reflect seasonal or other changes in the composition of raw milk or be a consequence of mineral additions during processing. The other milk powders have a lower protein concentration, and with the exception of Trufood Formula 4 a proportionately lower mineral content. This is due principally to the addition of different amounts of pure lactose but in the manufacture of Trufood Formula 4 lactose is added as whey. S.M.A. (Scientific Milk Adaptation), Lactogen, and Trufood Formula 4 are further modified by the addition of fat. Of the evaporated milks Carnation and Regal have a similar composition, but the sample

TABLE I—Results of Analyses of Milk Powders and Undiluted Evaporated Milks. All Values Expressed per 100 g Powder or Liquid Milk

Type of Milk	Protein (N × 6.38) (g)	Sodium		Potassium		Calcium (mg)	Phosphorus (mg)	Ca : P Ratio
		(mg)	(mEq)	(mg)	(mEq)			
Milk powders:								
Full Cream Cow & Gate ..	26.28	440	19	1,131	29	849	740	1.14
Ostermilk No. 2 ..	26.30	401	17	1,103	28	891	704	1.26
Golden Ostermilk ..	26.30	374	16	1,079	28	852	736	1.15
National Dried ..	25.84	436	19	1,198	31	911	733	1.24
Mothercare ..	22.65	400	17	967	25	791	628	1.25
Half Cream Cow & Gate ..	19.27	304	13	811	21	634	525	1.20
Ostermilk No. 1 ..	17.35	301	13	840	22	615	498	1.23
Lactogen ..	16.08	250	11	762	20	571	464	1.23
S.M.A. ..	11.6	198	9	558	14	428	342	1.21
Trufood Formula 4 ..	14.03	913	40	1,470	38	603	587	1.10
Evaporated milks:								
Carnation ..	8.80	141	6	360	9	279	236	1.18
Regal ..	8.36	132	6	380	10	269	233	1.15
Ideal ..	8.61	175	8	353	9	278	266	1.04

TABLE II—Composition of Milks Made up According to Instructions on Packets or Tins for a 1-month-old Baby Compared with Human and Cows' Milk. Values Expressed in g or mg per 100 g and mEq/kg Made up Milk

Type of Milk	Protein (N × 6.38) (g)	Sodium		Potassium		Calcium (mg)	Phosphorus (mg)
		(mg)	(mEq)	(mg)	(mEq)		
Human ..	1.7-1.2*	15†	7	52†	13	29†	14†
Cows' ..	3.3†	50†	22	150†	38	120†	100†
Full Cream Cow & Gate ..	2.9	48	21	123	32	92	88
Ostermilk No. 2 ..	2.9	44	19	122	31	98	78
Golden Ostermilk ..	2.9	41	18	119	31	94	81
Mothercare ..	2.5	51	22	124	32	101	80
Carnation ..	2.5	40	17	102	26	79	67
Regal ..	2.8	44	19	126	32	89	77
Ideal ..	2.6	52	23	105	26	83	79
National Dried ..	2.2	36	16	100	26	76	61
Half Cream Cow & Gate ..	2.4	38	17	101	26	79	65
Ostermilk No. 1 ..	2.2	38	17	106	27	77	62
Lactogen ..	1.9	29	13	89	23	66	54
S.M.A. ..	1.5	25	11	70	18	54	43
Trufood ..	1.8	115	50	185	47	76	74

*Kon and Mawson, 1950.

†McCance and Widdowson, 1969.

‡Kon and Cowie, 1961.

of Ideal milk analysed had a disproportionately high sodium and phosphorus content and an unusually low Ca/P ratio. This might be due to variation in the composition of raw milk or to additions during processing.

Table II shows the calculated composition of the milks when made up according to the instructions on the package or tin for a 1-month-old child (weight 8.0-10.0 lb—3,632-4,540 g) using the weights of powder per scoop stated by the manufacturers (table III), either added to or made up to a given volume, as this may make about 10% difference to the final composition. It should be noted that Lactogen, because the scoop is larger, is made up by adding one scoopful to 2 fl. oz (57 ml) water. Representative values for cows' milk and human milk are given for comparison.

Full Cream Cow & Gate milk, Ostermilk No. 2, Golden Ostermilk, and Mothercare milk reconstitute to milks which, so far as protein and mineral substances are concerned, resemble cows' milk diluted in a proportion of six parts to one of water (table III). Carnation, Regal, and Ideal evaporated milks when

reconstituted resemble cows' milk diluted in a proportion of four parts to one of water. National Dried Milk, though a full cream milk powder, is made up for an infant at 1 month old with three scoopfuls of milk powder to 4 fl. oz (114 ml) of water and resembles cows' milk diluted in a proportion of two parts to one of water. This milk and the others without added lactose are used with added sucrose. Half Cream Cow & Gate and Ostermilk No. 1 reconstitute to milks that have a similar protein

TABLE III—Comparison of Stated Scoop Weight with Mean Weight Obtained from Weighing Individually Six Separate Scoopfuls Following Manufacturer's Instructions Carefully

Type of Milk	Scoop Weight Stated by Manufacturer		Mean Scoop Weight of Six Scoopfuls (g)	Coefficient of Variation (%)
	(oz)	(g)		
Ostermilk No. 2 ..	1.5	3.54	3.69	7.1
National Dried ..	1.5	3.54	3.56	3.9
Full Cream Cow & Gate ..	1.5	3.54	3.3	3.3
Golden Ostermilk ..	1.5	3.54	3.5	2.9
Ostermilk No. 1 ..	1.5	4.1	4.43	2.7
Half Cream Cow & Gate ..	1.5	3.54	3.64	2.6
Mothercare ..	1.5	4.18	4.48	3.8
Lactogen ..	1.5	7.5	7.05	5.1
S.M.A. ..	1.5	4.1	4.55	2.8
Trufood ..	1.5	4.1	3.9	3.5

* Representative Full Cream Milk

Results of calculations for a hypothetical 4-kg infant fed different milks at volumes of 100 ml, 150 ml, and 200 ml/kg/day, showing how urine osmolality varies with insensible water loss, and with the volume of formula ingested. With an average insensible water loss (200 ml/day) and normal powers of urine concentration, the infant can remain in water balance on any milk; however, if insensible water losses increase or volume of feed is much reduced, renal concentrating ability may be exceeded and dehydration will occur.

and mineral composition to National Dried Milk. Half Cream Cow & Gate is based on a three-quarter cream cows' milk with added lactose; Ostermilk No. 1 is a full cream milk with added lactose. Lactogen, S.M.A., and Trufood Formula 4 when reconstituted have a lower protein content and, with the exception of Trufood Formula 4, a lower mineral content than the other milks because the addition of lactose and fat has resulted in a smaller proportion of the original cows' milk in the powder. Trufood Formula 4, reconstituted for use at 1 month, contains more than twice as much sodium as full strength undiluted cows' milk and nearly eight times as much as breast milk.

The results of calculations for a hypothetical 4-kg infant fed different milks at volumes of 100 ml, 150 ml, and 200 ml/kg/day are given in the graph, and it shows how the calculated urine osmolality varies with insensible water loss (see Methods). The curves show that the urine osmolality increases more and more steeply as insensible water loss rises and very steeply indeed when insensible water losses are high.

The weights of milk powder said by the manufacturers to be contained in a single scoop are shown in table III, and a comparison is made with the mean weights obtained from weighing individually the contents of six scoops of each milk. The scoop provided was filled by following the instructions on the container closely. The values correspond approximately, but they range from 11% too much to 7% too little milk.

Discussion

So many factors influence the final concentration of nitrogen and minerals in milks used for infant feeding that it is almost impossible to deduce exactly how much of these substances an infant is receiving each day. This information, however, is very important to the paediatricians because of its bearing on the infant's nutrition and ability to remain in water balance. All the milks we have examined are processed cows' milk, and because cows' milk has a higher mineral and protein content than breast milk these milks provide to a varying extent more protein (except S.M.A.) and more sodium, potassium, calcium, and phosphorus than does breast milk. The surplus of nitrogen and minerals not utilized for growth has to be excreted in the urine, which diminishes the infant's defence against increased extrarenal water loss.

It can be seen in the graph that with average insensible water losses of 200-250 ml/day (0.8-1.0 l/m²/day (Heeley and Talbot, 1955)) maximum urinary concentration (700-1,000 mOsm/kg H₂O (Winberg, 1959; Poláček *et al.*, 1965)) will not be exceeded on any milk correctly made up according to the manufacturers' instructions and given at the volumes recommended on the containers, which range from 150 ml/kg/day to about 200 ml/kg/day. Increasing the volume of feed taken shifts the curves to the right and increases the tolerance to rises in insensible water loss. On the other hand reduction in volume of feeds, such as might occur in quite minor illnesses in infancy, shifts the curves to the left, and this may result in negative water balance at normal rates of insensible water loss. This is shown by a shift to the left in the curve for Trufood Formula 4 but of course all the curves would be similarly displaced to the left.

Since breast milk has a very low solute load a wide range of insensible water loss can be tolerated without increasing the volume of feed and the amount of calories taken, so it seems unlikely in the breast-fed infants that thirst plays much part in determining caloric intake. In contrast, those milks presenting a high osmolar load diminish the range of insensible water loss that can be tolerated and, unlike the infant fed on breast milk, the urine may be concentrated to comparatively high levels with quite modest increases in insensible water loss. Since the stimuli that lead to urinary concentration also lead to thirst it is possible, in infants fed high solute milks, that thirst may from time to time determine caloric intake unless extra water is given. This would be likely to occur more often when solid food is

introduced early and might be a rather subtle but important factor in the development of infantile obesity (Taitz, 1971).

When extrarenal water losses are high—for example, during high fever, hyperpnoea, high environmental temperature, vomiting and diarrhoea, or when the renal concentrating power is diminished in renal disease—water balance may be jeopardized unless a low solute milk is used.

The calculated urine osmolalities are highest on Trufood Formula 4 because of its unusually high mineral content.* In this brand whey is added to cows' milk to make the casein:lactalbumin ratio more like that of human milk and to raise the lactose concentration. Whey is a byproduct of cheese making and contains, as well as lactose and lactalbumin, a large proportion of the sodium, potassium, and chloride of the original milk and also lactic acid—the last being formed by the bacterial "starters" that initiate the process of cheese making. Furthermore, in manufacture, sodium bicarbonate is added to adjust the pH of the whey. The addition of whey raises the osmolality of the milk, and the mean osmolality of the three batches of Trufood Formula 4 properly made up and measured in our laboratory was 446 mOsm/kg H₂O; in contrast the osmolality of cows' milk and human milk when secreted is the same as that of plasma—about 290 mOsm/kg H₂O (Kon and Cowie, 1961). The very high osmolality and sodium concentration of this milk is likely to be a particular danger to an infant developing gastroenteritis where the high incidence of hypernatraemia (Colle *et al.*, 1958) is associated with convulsions, an increased mortality (Finberg and Harrison, 1955), and permanent brain damage (Macaulay and Watson, 1967).

The calculated osmolar load imposed by Full Cream Cow & Gate, Golden Ostermilk, Ostermilk No. 2, Mothercare milk and the evaporated milks is less than that of Trufood Formula 4, and the relatively high contribution of urea to the total osmolar load in these milks may permit a higher maximum urinary concentration (Edelman and Barnett, 1960). National Dried Milk, S.M.A., and Lactogen in different ways have achieved a worthwhile reduction in solute load but they do not have the margin of safety provided by breast milk.

The preceding discussion was based on the calculated composition of the milks. In practice the final composition depends on the amount of milk powder in the scoop and the number of scoops used to make up a feed of a particular volume. Taitz and Byers (1972) analysed 32 samples of full cream milk formula feeds made up by mothers of infants attending a clinic. Twenty-one of these samples had concentrations of sodium 42% higher than our calculated value of about 21 mEq/l., and it is of great interest that their control samples, collected from the Jessop Hospital milk kitchen, were about 24% higher than our calculated value. The highest value recorded of 66 mEq/l. was from a sample of Trufood Formula 4 (L. S. Taitz, personal communication) and this is 32% higher than our calculated value of 50 mEq/l. for this milk and 10 times higher than the sodium concentration in breast milk (see table II). There are three possible explanations for this state of affairs: the scoops may contain too much powder, too many scoops may have been put in the feed, or too little water may have been used. Errors in fluid measurement are unlikely though they are reported (Simpson and O'Duffy, 1967; Hasnain and Abraham, 1968), and though errors in counting may be common it is unlikely that so many mothers put in more scoops than are advised on the packet. The most probable source of error is overfilling the scoop. This can produce very serious hypernatraemic dehydration and there are recent reports of several cases in which this has occurred (Stern *et al.*, 1972; Taitz and Byers, 1972). When the instructions on the container are followed carefully the mean scoop weight obtained can exceed the weight stated by the manufacturer by as much as 10% (table III). Since this

*The Trufood milk formula introduced in May 1972 has replaced Trufood Formula 4. The sodium concentration of this milk has been reduced to around 590 mg/100 g and the manufacturers plan to reduce it still further until it is close to that of full cream milk powders.

alone cannot account for the discrepancies noted by Taitz and Byers (1972) it is probable that in addition the instructions are not followed carefully.

We have begun to investigate the scoop weights obtained by mothers and the preliminary results of this study confirm that scoops are often overfilled. Since the instructions for filling scoops differ widely from brand to brand it is obviously important that all personnel concerned with infant feeding should be thoroughly conversant with the instructions for *each brand* of milk. However, the variations that we have found when following the instructions carefully raise the question of whether the scoop is a satisfactory measure at all. The danger of hyperosmolar feeding could be reduced by greater dilution of full cream milks with water, and allowing the baby a slightly larger volume of feed.

Conclusions

The addition of mineral substances in the manufacture of milks used for infant feeding probably alters the mineral composition slightly, but the addition of whey neutralized with sodium bicarbonate as used in the manufacture of Trufood Formula 4 results in an unusually high concentration of sodium. As the addition of even small amounts of substances may have an important bearing on an infant's nutrition and metabolism, we think that the chemical formulae and amounts of all substances added in the processing of such milks should be made readily available by the manufacturers. Furthermore, we suggest that as well as the content of protein the amounts of sodium, potassium, calcium, and phosphorus present in the powders or liquids should be written on the packet and expressed in both mg/100 g and mEq/kg. When a scoop is provided the weight of powder contained in a scoop should also be displayed on the container in both grammes and ounces. Milk powders that reconstitute to a composition close to that of cows' milk present an osmotic load to the kidneys that may endanger water balance in some circumstances. Since this risk is greatly increased by the tendency to overfill scoops and to make feeds too concentrated,

a specific inquiry on these points should be made when dealing with any case of dehydration or hypernatraemia. This risk could be reduced by recommending a greater dilution with water, by offering water as a drink during hot weather, and by making feeds up half strength during minor illness when there is anorexia.

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Inaccuracies in Measurement of Dried Milk Powders

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Summary

Infant feeds made up from dried milk are known to be hazardous if the mixture is too concentrated. Tests with five commercial brands of dried milk showed that nurses, midwives, and mothers often made up feeds incorrectly; in most cases the amount of powder used was excessive.

Fewer mistakes would be made if scoops were standardized or, better, if the milk was made up in small, accurately weighed packets.

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Introduction

Overfeeding of infants with cows' milk can be dangerous if it causes hypernatraemia and undesirable if it results in obesity.

Hyperosmolar dehydration (Finberg and Harrison, 1955; Colle *et al.*, 1958; Ziegler and Fomon, 1971; Taitz and Byers, 1972), and obesity due to overfeeding in infancy (Eid, 1970; Taitz, 1972; Shukla *et al.*, 1972) have been the subjects of many papers over the last two decades. Taitz and Byers (1972) described cases of hyperelectrolytaemia due to gross mistakes in the reconstitution of both dried powdered milk and evaporated liquid milk preparations, and Hytten and MacQueen (1954) drew attention to widespread inaccuracies in the making of feeds by mothers of different competence. Hytten and MacQueen's comprehensive study showed the wide variations in the content of calories, protein, fat, and carbohydrate which were found when reconstituted feeds were analysed in the laboratory.

Cows' milk contains more than three times as much sodium as human milk, and since the infant kidney cannot always excrete a solute load above 700 mOsm/l. (Winberg, 1959; Poláček *et al.*, 1965) then any reduction of fluid intake, increase in concentra-