SOYA BEAN FLOUR WITH DRIED MILK

A CHEAP AND EFFICIENT SUBSTITUTE FOR BREAST MILK

BY

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In many countries of the world the alternative to breast-milk feeding is usually the early demise of the infant. To this various factors undoubtedly contribute, but for immense numbers the primary factor is the absence or prohibitive cost of any adequate substitute for breast-milk. Fluid cow's milk is unobtainable throughout the vast tsetse-fly areas of Africa, and its prohibitive cost or scarcity place it beyond the reach of millions in India, China and other Asiatic countries ; moreover, dairy milk supplies may often fail in time of war. Even if obtainable, the excellence of fluid milk as a culture medium is fraught with danger to infants whose mothers are unable, whether owing to poverty or ignorance, to keep it under proper hygienic conditions. In London dried milk has, to a great extent, replaced fluid dairy milk as the basis for the artificial feeding of infants, to the great advantage of babies living in families in which there is considerable risk of food contamination. In Great Britain its cost to the working-class mother, who gets it from a welfare centre, is about the same as that of an equivalent amount of dairy milk, and to the necessitous it can be supplied free. In this respect members of the professional classes and others who are obliged to buy it from a chemist are heavily penalized, since its cost is often beyond their means. In any case, full-cream dried milk cannot be supplied at a cost which would make possible its general use among the native populations of Africa or in India and other Eastern countries.

Soya bean is a cheap foodstuff with many valuable qualities. The investigation here described is a comparison of the health and development of a number of infants, living in their own homes, who were given a mixture of equal parts of dried milk and soya bean flour, together with certain supplements, and of a control series given dried milk, the same supplements and also added iron. That is, the well-being of infants on the mixture of dried milk and soya was compared with that of another group of infants on the optimum artificial diet the author could devise. A mixture of equal parts of dried milk and soya bean flour could be sold for little more than half the price of dried milk alone. If costs of distribution could be cut down, this would bring it within the means of many mothers unable at present to buy dried milk, although

its price would unfortunately still remain too high for great numbers of people in India and other Eastern countries.

One of the important defects of cow's milk as a food for infants is its low iron content. Soya bean is said to be a popular remedy for anaemia in China (Adolph and Kao, 1932), and its iron content is fairly high. It was therefore hoped that a mixture of milk and soya bean would prevent the iron deficiency anaemia, and consequent lowered resistance to infection (Mackay and Goodfellow, 1931), which is so common in babies in every country where this problem has been investigated.

Types of soya bean flour

The legume soya bean contains little or no starch when ripe. Moreover, it contains much more protein than carbohydrate and a high percentage of fat (Bailey, Capen and Le Clerc, 1935 ; Horvath, 1938). Its use as a human foodstuff has been limited in most countries by its unpleasantly bitter taste, which can, however, be removed by certain processes of treatment (Bailey, Capen, and Le Clerc, 1935). In China, where it is a staple foodstuff, soya is used in a great many different forms, known in the literature as soymilk, soycheese, soycurd ; it is also used in a variety of sauces, as bean sprouts, and as roasted and salted beans (Miller and Wen, 1936). Fermentation plays a large part in the preparation, and may, it is said, extend over years. The composition even of two products known by the same name appears often to vary widely : soya bean curd, for example, may contain 8 per cent., 17 per cent., or 58 per cent. protein, according to whether it is ' fresh,' ' smoked ' or ' frozen ' (Horvath, 1938) ; and this difficulty of distinguishing between or assessing the composition or food value of the various preparations (including the flours) referred to in the literature is, for the ordinary reader, considerable.

Before describing the details of this investigation, some mention of the different varieties of soya bean flour may therefore be helpful, for medical readers in this country are not likely to be versed in these technicalities. If contributions on the experimental use of soya bean in human nutrition are consulted, references are found to flour made from heated beans, from unheated beans, from whole beans, and from pressed cake (i.e. the residue after extraction of oil) ; mention is also made of hydraulic meal, expeller meal, flour made by wet-grinding and flour made by dry-grinding, and to ' soy-milk powders.' The following summary of the main types of flour which have been used for feeding babies may be of assistance to other physicians wishing to employ the bean :

(a) The dry-ground flour from the whole unheated bean has a bitter taste, and the fat turns rancid with keeping, which greatly restricts its use. As will be shown later, experiments on rats have demonstrated that this unheated protein is not easily utilized (Osborne and Mendel, 1917) and the carbohydrates of the uncooked flour are digested with difficulty (Adolph and Kao, 1932). The composition of the whole bean shows considerable variation, depending both on the variety of the plant and on its conditions of growth (Horvath, 1938).

(b) Commercial soya flour is largely prepared from the residue left after extraction of the fat, the fat being used for many purposes. This flour (sometimes called ' oil meal,' ' expeller meal ' or ' hydraulic meal ') has lost most of its fat, and consequently presumably most of its vitamin A and D, and is in this respect a less valuable foodstuff. On the other hand, in the process of oil extraction the material may be raised to a high temperature, which increases the nutritive value of the protein (Hayward, Steenbock and Böhstedt, 1936).

Various processes are used for such oil extraction, known as 'expeller,' 'hydraulic' and 'solvent' processes. The nutritive value of the protein (Hayward, Steenbock and Böhstedt, 1936), the quantity of fat remaining and the amount of ash (Bailey, Capen and Le Clerc, 1935; Horvath, 1938) vary widely. According to Guy and Yeh (1938b), 'most of the soya bean flours on the American market are made from the residue or 'pressed cake' left after high-temperature extraction of oil from the bean. This flour is brown as a result of heating, and the nutritive value of its protein is good.

(c) 'Wet grinding' of the bean has been used by Chinese physicians on a small scale and by some American physicians (Tso, 1928; Guy and Yeh, 1938a; Rittinger and Dembo, 1932). This method, it is said, 'brings a certain amount of the protein into fine suspension and leaves the cellulose in the bulky residue which is filtered off' (Guy and Yeh, 1938a). The composition of a 'soy milk' made by this method varies widely, especially as regards protein and phosphorus content, the composition depending on the amount of boiling, stirring and evaporation. Guy and Yeh say that this soya milk 'is sold hot in Peking by street vendors, and taken by old people in place of tea. Contrary to some Western notions, it has not been usual, at least in the North (of China), to feed it to infants.' Horvath (1938) states that a wet-process flour has ample chance of turning rancid, which is a serious disadvantage, since rancidity causes destruction of vitamin A and D and the formation of toxic products.

(d) Hand-ground flour has been prepared from the roasted whole bean, and its protein should be well utilized, but so far as the author knows, it has only been used on a small scale (Guy and Yeh, 1938b).

(e) Of recent years soya flour has been prepared by the patent Berczeller process (Bailey, Capen and Le Clerc, 1935). This was devised in order to obtain a commercial flour of high fat content and good keeping quality, devoid of the unpleasant strong taste of the bean. The flour used in the present investigation was prepared by a modification of this process and is sold under the proprietary name of soyolk, the makers claiming that the taste is better than that of Berczeller flour. The Berczeller process is described by Bailey, Capen and Le Clerc as follows: the beans are cleaned, subjected to the action of saturated steam for ten to fifteen minutes, dried and cracked to remove the husks. The germ is removed in this process. The flour is subjected to steam distillation, which removes some of the volatile material responsible for the bitter taste. Soyolk is a fine, cream-coloured powder with very little taste, and what taste it has has been described as neutral. No chemicals are used in its preparation. The makers claim that the protein is of high biological value, but, so far as the author is aware, this has not been investigated by feeding experiments either with soyolk or with Berczeller process flour. The flour can be kept for long periods without turning rancid. Several other patented processes for obtaining a flour with a high fat content which does not turn rancid are given by Bailey, Capen and Le Clerc (1935).

(f) There are also on the market so-called 'soy-bean-milk powders,' preparations of soya flour mixed with other substances, with the object of rendering them suitable for infant feeding. For example, the flour from pressed cake has been marketed in America with additions of cereal, oil and minerals (Hill and Stuart, 1929), but this flour is apparently deficient in vitamin A. Blackfan and Wolbach (1933) recorded the appearance of keratomalacia in a baby fed on such a 'soy milk.'

From the foregoing it is obvious that when considering reports on the use of soya bean flour in human nutrition it is necessary to keep in mind what type of flour was used and whether or not various additions have been made to it in the course of preparation. Even apart from such additions, the differences are wide: the nutritive value of the protein, the percentage present, the amount

of fat and its keeping properties, the digestibility of the carbohydrate, the amount of vitamins present and, not least important, the amount and balance of the mineral elements all vary widely according to the method of preparation.

The composition of soyolk and yolac

The mixture of dried milk and soya flour (soyolk) used in this investigation was given the name of 'yolac.' Yolac was prepared by Messrs. Cow and Gate by mechanical mixing of equal parts by weight of their full-cream dried milk powder and soyolk. An attempt was made in the first instance to incorporate soyolk in fluid milk and then dry the mixture, but as the heat caused chemical changes in the soyolk this method was discarded in favour of mechanical mixing of the two powders.

TABLE I
ANALYSES OF DRIED MILK, SOYA BEAN FLOUR, AND YOLAC

	DRIED MILK		SOYOLK				YOLAC				
	FIRM'S FIGURES A		CRON- SHAW B		KUPEL- WEISER C		WIDDOW- SON D		FROM A and B		WIDDOW- SON
Total nitrogen (gm. per 100 gm.)	—		—		—		6.49		—		5.13
Protein	26.6	91.5	44.2	78.9	41.5	81.0	40.5	84.9	35.2	84.9	32.2
Fat	27.3		20.6		20.3		19.9		23.9		25.7
Carbohydrate	37.6		14.1		20.0		20.6		25.8		27.3
					to 24.8						
Water	2.6	8.6	11.1	14.8	9.0	—	—	11.6	6.8	11.6	3.0
Ash	6.0		3.7		—		—		4.8		—
Calcium (mgm. per 100 gm.)	843		—		270		214		—		553
Phosphorus	742		—		—		352		—		500
Phosphoric acid	—		1340		1120		—		—		—
Total iron	—		—		—		16.2		—		9.6
Available iron	—		—		—		13.2		—		8.1
Magnesium	96		—		—		219		—		158
Calorie value (per 100 gm.)	517		431		—		—		474		483
Protein	109		181		—		—		145		132
Fat	254		192		—		—		223		239
Carbohydrate	154		58		—		—		106		112
Calorie value per drachm (60 grains) . .	20.1		16.8		—		—		18.5		18.9

Table 1 gives the composition of the dried milk used (Messrs. Cow and Gate's figures) and the composition of soyolk (two sets of figures supplied by the firm marketing the flour and an analysis kindly carried out by R. A. McCance and E. M. Widdowson) ; and the composition of yolac (as calculated from the figures supplied by the two firms, and from direct analyses by McCance and Widdowson).

The analyses show general agreement. Soyolk contains over 40 per cent.

protein, about 20 per cent. fat and 20 per cent. carbohydrate. It contains about a quarter as much calcium and about half as much phosphorus as dried cow's milk, and about twice as much magnesium and about eight times as much iron. Since soya flour contains less calcium than phosphorus, most workers using soya flour for infant feeding have added a calcium salt in order to augment the calcium intake (Tso, Yee and Chen, 1928 ; Hill and Stuart, 1929 ; Chang and Tso, 1931 ; Rittinger and Dembo, 1932 ; Stearns, 1933 ; Rittinger, Dembo and Torrey, 1935 ; Guy and Yeh, 1938 a, b). Sodium and chlorine content are not given in this table, but these also are low compared with dried milk, and have usually been added to 'soya-milk' for infants.

Yolac was used mixed with water in the proportion of approximately one in eight. In this mixture the percentage of protein is high compared with average cow's milk, and the percentages of fat and carbohydrate are distinctly lower (see table 2). The percentage of iron in yolac is about five times as much as in dried milk (see table 3), the calcium two-thirds as much, the phosphorus two-thirds as much and the magnesium about one-and-a-half times as much (using Messrs. Cow and Gate's figures for the percentages of calcium, phosphorus and magnesium in the dried milk, and Widdowson and McCance's figures for yolac). Therefore in this mixture of soya flour and milk, the quantity of calcium present and the ratio of calcium to phosphorus should be adequate without further adjustments. As cow's milk contains, say, twice as much sodium and chlorine as breast milk (Schall and Heisler, 1917), a mixture of equal parts of dried cow's milk and soyolk would presumably supply ample of these substances for the infant's needs.

TABLE 2
PERCENTAGE OF PROTEIN, FAT, AND CARBOHYDRATE IN YOLAC
COMPARED WITH MILK

	DAIRY MILK (HUTCHISON AND MOTTRAM)	DRIED MILK COW AND GATE, 1 IN 8 (FIRM'S FIGURES)	YOLAC, 1 IN 8 (WIDDOWSON)
Protein	3 to 4	3.3	4.0
Fat	3.5 to 4.5	3.4	3.2
Carbohydrate	4 to 5	4.7	3.4
Mineral matters	0.7	0.8	0.6*

* Firm's figures.

TABLE 3
IRON IN DRIED MILK AND YOLAC (WIDDOWSON)

	DRIED MILK COW AND GATE	YOLAC
Mgm. per 100 gm.	2.00	9.70
	1.81	10.91
	2.03	9.38
	—	8.37
Average total	1.95	9.59
Average available	1.95	8.15
Mgm. per 1 lb.	8.8	43.5

The calorie value of 1 drachm (60 grains) of Cow and Gate full-cream dried milk is approximately 20, and of yolac 19 (see table 1) ; thus the calorie value of a one in eight mixture of yolac is about that of cow's milk. The infants' feeds were prepared by mixing the yolac or dried milk with hot water. The mixture was not boiled after mixing. The bulk of a given weight of yolac was about the same as that of the dried milk used, so the mothers were provided with the Cow and Gate measure for both yolac and dried milk. If allowed to stand the soyolk began gradually to sink to the bottom, but shaking reproduced a satisfactory mixture.

The nutritive value of soya bean flour with special reference to soyolk

Horvath (1938), who is an authority on the soya bean, gives in a recent article an extensive bibliography on the composition and nutritive value of the bean and its use in human nutrition. References are confined in this paper to articles bearing on the use of soya flour for infant feeding which are likely to be accessible to medical readers, but no attempt has been made to cover the whole literature regarding even this limited field.

The main protein of soya bean is a globulin, glycinin. The basic amino acids have been determined by Bruce Jones and Waterman (1921) by the van Slyke method and are set out in their article. The nutritive value of the protein, as determined by the growth of rats, has been examined by Osborne and Mendel (1917), and among other later workers by Hayward, Steenbock and Böhstedt (1936). They found that the raw bean provided an inefficient protein, but that autoclaving the bean (one and a half hours' heating with steam at 17 pounds pressure) or alternatively adding 0.3 per cent. cystin practically doubled the nutritive value of the protein fraction. Dry-heating in the laboratory for one and a half hours failed to improve the nutritive value. They concluded that a high temperature so altered the protein as to cause some essential fraction to become available for absorption and metabolic use. They drew attention to the wide variation in the nutritive value of the protein of different commercial flours. The brown commercial flours, made after the extraction of oil at high temperatures, or flour from the residue of 'solvent' methods of oil extraction were as good a source of protein as the bean autoclaved in the laboratory. The makers of soyolk claim that the protein of this flour is also of high biological value, but whether or not the degree of steam heating they use is sufficient to ensure the maximum nutritive value of the protein does not seem to have been determined.

The carbohydrate of the ripe bean is said to be present in the form of galactans, pentosans and insoluble cellulose, with small amounts of cane sugar and reducing sugar. Estimates of the sugar content vary (Rittinger and Dembo, 1932 ; Bailey, Capen and Le Clerc, 1935 ; Horvath, 1938). One author states that there is as much as 9 per cent. of cane sugar (Ruhräh, 1909). Some starch is present when the bean is not fully ripe. According to different analyses, the fibre content is usually between 2 per cent. and 4 per cent. The flour made from shelled beans contains little cellulose (Ferreé, 1929).

The composition of soya bean fat is discussed by Rittinger and Dembo (1932). They say that it is liquid at room temperature and contains a high percentage of unsaturated acids. The fat of the untreated whole-bean flour quickly turns rancid, and this destroys the vitamins A and E present (Horvath, 1938). The Berczeller process greatly improves the keeping properties of the fat. Soyolk, it is claimed, has been kept satisfactorily for two years in a laboratory ; in any case, during the course of the present work none of the

mothers complained of any rancidity, although, owing to home circumstances, the food was probably often kept in hot rooms. The bean is rich in phosphatides (Horvath, 1938).

The vitamin value of one ounce of the bean is given by Rittinger and Dembo (1932) as follows : vitamin A 560 units ; vitamin D 28 Steenbock units ; vitamin B complex 22 units. Sherman (1937) gives the average vitamin A value of cow's milk as 292 international units per 100 grammes, and, on this basis, a full-cream milk powder, if there were no destruction of vitamin A, would have about 654 units per ounce, as compared with 560 units in the soya bean. The range of values given in the literature for cow's milk is, however, extremely wide, varying from 15 to 700 units per 100 c.c. according to different authors (Willstaedt and With, 1938). The cow's diet plays a large part in determining the vitamin A value of the milk secreted. Sherman considers that such figures give an exaggerated and erroneous idea of its usual variability, which he holds to be fairly small. What the actual variation may be or the degree of error in the various methods of estimation employed it is impossible for the ordinary physician to judge. Wan (1932) compared the vitamin B content of dried milk and soya bean, and arrived at the conclusion that soya bean contained two-thirds as much B₂ and three times as much B₁ as the full-cream dried milk, klim, with which he compared it. The bean also contains vitamin E (Horvath, 1938) and vitamin K (Dam, 1935).

The iron content of soya bean is high. According to Widdowson's figures (see table 3), it contained about eight times as much as the dried milk with which it was compared, and most of this iron is in the so-called available form. Adolph and Kao (1932) state that soya bean cheese or curd is regarded by the Chinese as a cure for anaemia, and they cured rats of 'milk anaemia' by feeding them on the whole soya bean which had been ground and cooked.

As already pointed out, soyolk contains less than two-thirds as much calcium as phosphorus, whereas cow's milk contains more calcium than phosphorus. The calcium-phosphorus ratio is of importance because a relative deficiency of calcium would predispose to rickets and tetany. The mixture of dried milk with soyolk should, however, supply a safe calcium-phosphorus ratio. Horvath (1938) states that some workers investigating metabolism on soya bean diets have upset the metabolism of calcium by adding fat to the soya bean, which is already rich in fat, and that poor calcium retention has been due to excess of fat. Adolph and Shen (1932) have shown that calcium is well-utilized by adults on soya bean diets and point out that the bean is an important source of calcium for the Chinese.

The use of soya bean in feeding infants and children

During the last thirty years reports have appeared on the use of various 'soya milks' for feeding infants and young children. In 1909 Ruhräh, the pioneer in this work, used gruels made from boiled beans (1909a), and from dry-ground flour with added sugar (1909b), as a temporary diet for babies with and without summer diarrhoea, for marasmic infants and for subnormal children. He gives few details, but was apparently satisfied with his results. He has also given soya gruel with barley flour, salt and condensed milk, (Ruhräh, 1915). Sinclair (1916), using for short periods a similar gruel from dry-ground flour without added sugar for seventy-four cases of diarrhoea under three years old, states that forty-four did well.

Hill and Stuart (1929) used a flour from pressed cake (i.e. the residue from soya bean after extraction of oil), to which were added barley flour, olive oil, sodium chloride and calcium carbonate, the mixture going under the name of sobee. They say that about forty infants took it well and thrived. Stearns

(1933), who investigated the nitrogen, calcium and phosphorus metabolism of two children on such a mixture, considered the retention of calcium and phosphorus unsatisfactory, but found the relative retentions of nitrogen, calcium and phosphorus improved by substituting dicalcium phosphate for calcium carbonate. Moreover, this 'soy milk powder' is also deficient in vitamin A, for, as already mentioned, Blackfan and Wolbach (1933) have recorded the development of keratomalacia in a six-month-old infant fed on it.

The largest series of cases yet published are those of Rittinger with his associates Dembo (1932) and Torrey (1935), who have given soya milk to 205 infants. They gave at first a wet-ground flour, with added sugar, fats and minerals. The majority of babies gained well, and had three to four large green soft stools daily. Some with six or seven stools daily did not thrive. The stools improved if the mixture was well boiled. Nevertheless with a wet-ground flour which may turn rancid, causing destruction of vitamin A and vitamin E, there is presumably considerable risk of symptoms of vitamin A deficiency developing (Horvath, 1938). As already pointed out, the composition of wet-ground flour varies widely with the details of preparation. Later, Rittinger and his colleagues (1935), used a dry-ground flour with or without partial breast feeding, adding more carbohydrate than in their earlier work. The infant's weight curves paralleled the Holt line for the most part, but the majority were below it. Adding skimmed milk and wheat germ to the diet improved growth. They carried out x-ray and biochemical investigations, and blood counts in some cases, with normal results in nearly all instances.

In China, Tso and his associates (1928, 1931) used a wet-ground flour, with additions of sodium chloride, sugar and other substances, and carried out various metabolic studies on infants. They concluded that calcium is inadequate in such 'milk' (Tso, Yee and Chen, 1928), and that in order to furnish sufficient protein 18 per cent. of the total calorie intake should be provided by the protein (Tso and Chu, 1931). Chang and Tso (1931) suggest the use of a wet-ground flour with added sugar, dried by a spray process, to which is added before use more sugar and calcium lactate, sodium chloride, cod-liver oil and cabbage water. Following this work, a wet-ground flour, prepared at the local health station, was used in Peiping by Guy and Yeh (1938a), because of the urgent need of an artificial food cheaper than cow's milk. They too made various additions to the flour (sugar, starch, calcium lactate, sodium chloride). They used this 'soymilk' as a supplement to breast feeding, giving, like Chang and Tso, cod-liver oil and cabbage soup to supply vitamins D and C. They found that the babies had less muscular vigour than the breast-fed ones and were subnormal in weight. They concluded that this method of preparation was cumbersome and impractical for their purpose. Later they fed forty-nine babies on a similar mixture but used a hand-ground flour made from roasted beans (1938b). They considered these results satisfactory in spite of a few failures.

Reid (1935) after satisfactory tests on young rats and puppies of soya flour (Berczeller process) with egg yolk, sugar, peanut oil, calcium lactate and sodium chloride, suggested its use for infants. Such a powder could hardly be supplied at a low cost, and Horvath (1938) says the egg yolk is subject to deterioration in such blends and adds unnecessarily oil and phosphatides to soya flour which is already rich in these substances.

Soy milk has been suggested for the treatment of babies with eczema (Hill and Stuart, 1929 ; Becker, 1934 ; Klein, 1933). The theoretical grounds for its use put forward by different workers are that the eczema may be due to milk sensitization, or that the bases present in soya bean or alternatively its unsaturated fatty acids may be beneficial. Because a soya bean diet renders the urine alkaline, it has been used for the treatment of urinary infection

with *b.coli* (Mader, 1932), but with the drugs now available soya flour is unlikely to be employed.

Soy milk has been used for the treatment of diarrhoea, and the Dionne quintuplets were given 'soy acidophilus milk' (Horvath, 1938).

Caldwell (1933) in New York used soya bean flour (prepared by the Berczeller process), combined with other foodstuffs, as a supplement to the diets of sixty-six young children in poor economic circumstances. The average increase in weight of the soya group was distinctly superior to that of fifty controls, but few details are given. Aykroyd and Krishnan (1937) used cooked soya bean as a supplement to the diet of school-children in Southern India with little benefit, though the children's diets were defective in various respects, as proved by the marked benefit to growth and general health which resulted from a supplement of skimmed milk. They conclude that the soya bean does not make good the particular deficiencies common in these diets.

To summarize, no authors have published any detailed statistical results whereby the progress of babies given soya preparations can be compared with that of similar babies living under similar conditions but given preparations of cow's milk. Judging by the statements and conclusions of the authors quoted above, it seems, as might be expected, that babies fed on soya flours without any admixture of cow's milk do not, on the whole, make as good progress as babies having milk as the basis of their diet.

Horvath (1938) quotes the following sentences from a recent publication of the Food Research Division of the U.S. Department of Agriculture: 'The most expensive food constituents are minerals, vitamins, proteins and fats. Soy bean flour is rich in all these food constituents and yet relatively cheap.' It is, in fact, one of the cheapest sources of protein and calcium (Bailey, Capen and Le Clerc, 1935). It is hoped that the investigation here described may encourage the large-scale use in infant feeding of a mixture of milk with this cheap foodstuff in those parts of the world where a sufficiency of milk alone is beyond the means of the people.

Nature of present investigation

The present investigation was carried out in the out-patient department of the Queen's Hospital for Children from August, 1935, to March, 1938, the babies concerned living in their own homes. They were divided into three groups. One group was given a mixture of equal parts of dried milk and soya bean, which the makers have called yolac; the other two groups were given dried milk with added iron. (A few babies in each group received some breast milk, usually only for a short period after inclusion in the investigation.) The progress of the latter two groups, which differed only in their vitamin A intake, was so similar (Mackay, 1939) that, except when otherwise stated, they will together be regarded as the control group. It can safely be assumed that both these control groups had sufficient vitamin A.

Group 1 received yolac (i.e. dried milk plus soya bean), sugar, orange juice and cod-liver oil emulsion. Of the two control groups, group 2 received dried milk with added iron, sugar, orange juice and cod-liver oil emulsion; and group 3 received dried milk with added iron (called hemolac), sugar,

orange juice and a vitamin D emulsion. From six months old, in addition to yolac or hemolac, all children received table food.

Full records were kept of the clinical condition of the babies, together with any complaints by the mothers of fretfulness, crying, failure to take the feeds, or other feeding difficulties, and the presence of constipation or looseness of the bowels was carefully noted. The results have been analysed, and objective results and subjective impressions resulting from this comparison are set out in this paper.

Clinical material. **NUMBER OF BABIES.** A total of 225 babies were taken for the purpose of this investigation, but only 150 were available for the final statistical comparison. Of these 150, 48 were yolac cases and 102 were controls, 49 of the latter getting iron-containing dried milk with cod-liver oil, and 53 the same dried milk and iron with vitamin D and no supplement of vitamin A. An analysis of the reasons for the exclusion of 75 cases is given under the heading of results.

AGE OF INFANTS. Of the 150 children included in the final comparison, the ages when first seen were as follows : Under one month, 13 cases (8·7 per cent.) ; one to two months old, 46 cases (30·7 per cent.) ; two to three months old, 54 cases (36·0 per cent.) ; three to four months old, 34 cases (22·7 per cent.) ; four to five months, 3 cases (2·0 per cent.). Hence over three-fourths of the children were under three months old when first seen.

DURATION OF ATTENDANCE AND FREQUENCY OF ATTENDANCE. No child was included who did not attend and receive yolac or iron-containing dried milk for over four weeks. The period of attendance varied from thirty-five days to twenty-six months, and averaged nine months. Mothers were asked to bring their babies up to the hospital at first twice or once in the week, and when established on their diet at fortnightly intervals. Many were seen fortnightly with great regularity. They were examined naked by the author. Any child who was not seen at these clinics for a period of six weeks, even though taking the food prescribed, was reckoned as having ceased to attend.

CLINICAL CONDITION OF INFANTS. As it was decided to test yolac both as regards its tolerance by infants in varying health and its suitability in other respects, infants brought up to hospital for a variety of complaints were included in the investigation, and many of these babies had suffered from feeding upsets and from infections before they were seen. The majority were under normal weight when first included and a few were emaciated or in very poor condition. The average birth weight, as given by the mothers, was 7 pounds 0·8 ounces.

ECONOMIC STATUS OF FAMILIES. Many of the parents were in poor circumstances (e.g. the father was a casual manual worker or unemployed and was often receiving a milk grant or other help from public or charitable sources), but some were in much better circumstances, e.g. small traders, policemen, and others in regular work.

The diet given. As a jumping-off ground, most babies at their first attendance were put on to a full-cream dried milk. A few babies in each group received some breast milk. During the second week of attendance they were gradually changed from the unmedicated dried milk to either yolac

or iron-containing dried milk, approximately half a drachm of the new food being substituted daily. Thus to change a baby from three drachms per feed of unmedicated dried milk to three drachms per feed of yolac or iron-containing dried milk would take six days. In the same way, a week was usually taken to work up to the full dose of cod-liver oil or vitamin D emulsion. The same principles of feeding were applied to all the babies, whatever the group: the same additions of sugar were given, together with a supplement of orange juice and cod-liver oil (or vitamin D for those in group 3), the only difference being that the yolac group received yolac and the controls iron-containing dried milk. From about six months old, mixed food was started, and the yolac or hemolac correspondingly reduced, so that by about seven months old the baby instead of getting about one-and-three-quarters or two pounds in the week (providing about one litre daily), received about one to one-and-a-quarter pounds each week (providing say one pint or a little over half a litre daily), with the gradual addition of fish, eggs, puddings (usually made from dairy milk), vegetables and fruit. Meat was usually given before ten months old.

HEMOLAC. The dried milk (hemolac) used was a full-cream, roller-process milk, in which iron and ammonium citrate had been incorporated before drying in the proportion of $31\frac{1}{2}$ grains to the pound. This quantity is sufficient to prevent nutritional anaemia. The mothers were asked to obtain the milk from the hospital, where it was sold to them at cost price or exchanged for any other dried milk given by the borough to a necessitous mother. A considerable number of mothers obtained hemolac from their welfare centres, in which case it was not possible to check the mother's account of the amount given to the baby by the record of the amount sold. At about six months old most babies were receiving the equivalent of say one-and-three-quarter pints (about one litre) of dairy milk daily. After seven months the hemolac allowance was generally the equivalent of about one pint daily of dairy milk, but in addition many babies received not infrequently milk pudding made from dairy milk, and this might account for another quarter of a pint of milk daily.

YOLAC. The composition of the yolac has already been discussed. It was used in the same quantities as the hemolac and in similar dilution. After six months old these babies, like the controls, were given milk puddings made with dairy milk.

SUGAR. Usually $1\frac{1}{2}$ drachms (say 6 grammes) of castor or granulated sugar was added to each feed of hemolac or yolac. The calories in added sugar varied between 60 and 135 in the day.

VITAMIN C. Mothers were advised to give their babies not less than one teaspoonful of orange juice daily. Much larger quantities were often given, especially to constipated babies, and as there was less constipation in the yolac group these babies received less orange juice than the controls. From six months old various fruits and vegetables were included in the diet.

VITAMINS A AND D. Babies of groups 1 and 2 were ordered cod-liver oil emulsion, 3 drachms (say 11.5 c.c.) daily of a 50 per cent. emulsion, providing them with $1\frac{1}{2}$ drachms (nearly 6 c.c.) of cod-liver oil daily, say 580–870 international units of vitamin D and 4600–7000 international units of vitamin A (determined by the spectrophotometer). The oil was bought from Messrs. Allen and Hanbury, and these values have kindly been supplied by Mr. Norman Evers. Babies of group 3 were ordered an emulsion of vitamin D (calciferol) providing them with say 1575 international units daily. It has been shown elsewhere (Mackay, 1939) that babies of group 2 and 3 were similar in rate of

gain in weight, general morbidity rates, incidence of infections of eyes and of mouth, incidence of lesions of the skin (whether infectious or non-infectious), and in skin texture. Hence it has been assumed that they received their full requirements of vitamin A ; and groups 2 and 3 have, therefore, been amalgamated to form a larger control group. As already stated, the quantity of vitamin A and carotene in soya bean is said to be of the same order as would be present in dried milk if no destruction occurred during the process of drying.

Results

The general progress of most babies in both yolac and control groups was good. Previously when the author has had under observation a group of babies receiving extra iron with their milk and another group getting no extra iron, babies of the latter group have looked definitely inferior (Mackay and Goodfellow, 1931). As a group the yolac babies did not look inferior to the hemolac babies, and so by inference they looked better than babies fed on cow's milk without extra iron. Below are analysed, first, the findings regarding the 150 children finally included in this investigation and, secondly, the information available regarding the 75 children excluded from the statistical comparison, since it is necessary to consider whether any children were excluded because they did not tolerate the food given them.

The 150 babies finally included in the comparison. At the beginning of the observation the yolac group and the controls were fairly evenly matched (see table 4). The average age tallied to within one day, the average weight differed by about one ounce and the balance of sexes was similar : in the yolac group 56 per cent. were males, in the control group 61 per cent. The average birth weight, as given by the mother, was 7 pounds 1·1 ounces for yolac cases, and 7 pounds 0·7 ounces for controls. The average period of attendance was, however, nineteen days longer in the yolac group, the latter averaging nineteen days older at the end of the observation. Yolac babies attended for an average period of 9 months 12·6 days ; controls for 8 months 23·6 days. The average time from the first attendance taken to change the babies completely on to a diet of yolac was eighteen days, and on to hemolac fifteen days. The change was begun about one week after the first attendance. The babies getting some breast milk, of which there were a few in each group, are excluded in estimating the time taken to change babies wholly on to yolac or hemolac. The amount of breast milk was usually small, and the average gain in weight of these babies was not better than that of the whole groups.

WEIGHT. The yolac babies gained on the average rather more slowly than the controls : yolac babies 3·98 ounces and hemolac 4·30 ounces weekly ; the difference per month, however, only amounted to $1\frac{1}{2}$ ounces (see table 4). If the cases are sub-divided by season the control groups show a slightly superior gain both in winter and in summer. Again, if a weight curve is plotted from the average weight at each monthly birthday (see chart I and table 5), the controls are superior in weight from five months to eighteen months, and thereafter the number of babies is small. At six months this difference is about

13 ounces, at nine months about 9½ ounces, at twelve months about 2 ounces, and at eighteen months about 7 ounces. Taking the figures from this chart, we find (see table 6) that, between five and eighteen months old, the average monthly gain in the two groups differs by less than 1 ounce. But from two to five months old the controls gain rather better, i.e. 1 pound 10½ ounces monthly as against 1 pound 8½ ounces in the yolac group. Whether the difference in the rate of gain is statistically significant or not was not determined. Owing to the different length of attendance the process of determining this would be laborious, and in any case the difference is small.

CHART I

TABLE 4

THE AGES AND WEIGHTS OF THE YOLAC CASES AND CONTROLS COMPARED

WHOLE PERIOD	NO. OF CASES	SEX M. F.	AVERAGE AGE		AVERAGE ATTEND- ANCE, MTH. DAY	AVERAGE WEIGHT		AVERAGE TOTAL GAIN, LB. OZ.	AVERAGE WEEKLY GAIN, OZ.
			FIRST ATTEND- ANCE, MTH. DAY	LAST ATTEND- ANCE, MTH. DAY		FIRST ATTEND- ANCE, LB. OZ.	LAST ATTEND- ANCE, LB. OZ.		
Yolac cases	48	27 21	2 7.9	11 20.5	9 12.6	9 2.8	19 3.3	10 0.5	3.98
Controls	102	63 39	2 8.1	11 1.7	8 23.6	9 1.6	19 3.4	10 3.4	4.30
SUBDIVIDED BY SEASON	NO. OF PERIODS *								
SUMMER—									
Yolac cases	50		6 6.6	9 9.7	3 3.1	14 3.2	17 10.8	3 7.6	4.18
Controls	92		5 27.9	9 16.5	3 18.6	14 1.2	18 4.6	4 3.4	4.34
WINTER—									
Yolac cases	64		6 1.7	10 19.9	4 18.2	13 12.3	18 8.3	4 12.0	3.85
Controls	143		6 3.6	10 2.5	3 28.9	13 14.8	18 7.4	4 7.4	4.27

* In the seasonal subdivisions children attending during more than one summer or winter period cause the number of 'periods' of attendance to be in excess of the number of children attending.

TABLE 5

AVERAGE WEIGHT AT EACH MONTH OF AGE—FIGURES ON WHICH CHART I IS BASED

AGE IN MONTHS	1	2	3	4	5	6	7	8	9	10	11
Yolac cases : Average weight .. No. of cases	lb. oz. —	lb. oz. 9 5·5 16	lb. oz. 11 2·6 34	lb. oz. 12 9·2 44	lb. oz. 13 15·2 42	lb. oz. 14 15·9 42	lb. oz. 16 7·2 38	lb. oz. 17 8·8 31	lb. oz. 18 10·4 28	lb. oz. 19 13·7 25	lb. oz. 20 9·6 22
Controls : Average weight .. No. of cases	7 1·4 7	9 2·6 34	10 13·0 69	12 8·4 87	14 2·0 86	15 12·8 75	17 3·7 66	18 16·6 62	19 4·0 54	20 1·0 50	20 15·3 45

AGE IN MONTHS	12	13	14	15	16	17	18	19	20	21	22
Yolac cases : Average weight .. No. of cases	lb. oz. 21 5·2 17	lb. oz. 21 12·3 14	lb. oz. 22 3·7 14	lb. oz. 22 15·2 13	lb. oz. 23 6·6 12	lb. oz. 24 2·8 12	lb. oz. 24 4·1 10	lb. oz. 25 8·4 7	lb. oz. 26 3·1 7	lb. oz. 25 10·8 6	lb. oz. 26 1·8 6
Controls : Average weight .. No. of cases	21 7·1 40	22 0·7 34	22 14·9 27	23 11·4 24	23 13·6 20	24 4·4 20	24 11·0 16	25 3·7 13	25 7·5 11	25 11·1 11	26 10·0 8

TABLE 6

RATE OF GAIN IN WEIGHT AT DIFFERENT AGES (TAKEN FROM CHART I) YOLAC CASES AND CONTROLS COMPARED

AGE PERIOD	MONTHLY GAIN	
	YOLAC CASES	CONTROLS
2-5 months	1 lb. 8·6 oz.	1 lb. 10·5 oz.
5-12 months	1 lb. 0·8 oz.	1 lb. 0·7 oz.
12-18 months	0 lb. 7·8 oz.	0 lb. 8·7 oz.

HAEMOGLOBIN LEVEL. The haemoglobin level was examined monthly for babies in the yolac group and babies in group 2 (i.e. those ordered hemolac and cod-liver oil) (see chart II and table 7). The blood was taken from the heel from a prick with a cutting needle, and was estimated with a Haldane haemoglobinometer (Price Jones standard) (Mackay, 1933). This control group had at each month from five to eighteen months old an average haemoglobin level of over 80 per cent., excepting at fourteen months old, when the figure was 79·5 per cent. ; the average of all the estimations (304) done on

babies between the ages of five and eighteen months was 82·1 per cent. This average has been somewhat lowered by a few babies who were said to be having hemolac bought from a welfare centre, but who were pretty certainly not getting their medicated milk regularly. Two babies in this series had at some time after four months old a haemoglobin level under 70 per cent., presumably from this cause.

CHART II

TABLE 7

HAEMOGLOBIN LEVEL AT EACH MONTH OF AGE—FIGURES ON WHICH CHART II IS BASED

AGE IN MONTHS	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Yolac cases—									
Haemoglobin percentage	86.7	73.5	78.4	81.4	83.4	81.5	79.4	77.4	79.0
No. of cases	14	30	40	43	37	39	34	29	23
Controls (Group 2 only examined)—									
Haemoglobin percentage	87.0	72.5	75.9	79.2	82.8	83.4	82.7	83.7	81.3
No. of cases	9	28	37	40	39	38	34	30	25

AGE IN MONTHS	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19
Yolac cases—									
Haemoglobin percentage	75.3	76.7	79.6	79.0	78.2	78.7	84.4	85.6	84.6
No. of cases	20	19	12	11	10	11	9	5	8
Controls (Group 2 only examined)—									
Haemoglobin percentage	82.0	81.7	80.2	80.0	79.5	81.2	82.0	82.9	81.2
No. of cases	20	22	19	18	15	13	12	10	9

The majority in the yolac group showed a satisfactory haemoglobin level, but there were some exceptions. Four babies between the ages of eight and twelve months had a percentage between 46 and 60. The baby who dropped to 46 per cent. was a small twin suffering from diarrhoea, and was consequently off yolac at the time his haemoglobin reached this level, though it had been dropping previously on yolac. The other three babies were getting yolac

regularly. These four babies were given ferrous sulphate, and responded to it, showing that they had suffered from a deficiency of iron. Five other babies had at some time after five months old a haemoglobin level below 70 per cent., making nine in all below 70 per cent., as against two included in the 'iron' group, both of whom probably failed to get their iron ration. The majority in the yolac group had a haemoglobin level well above that to be expected in babies given dried milk with no added iron (Mackay, 1933). In chart II and table 7 are shown the average haemoglobin levels of yolac babies. (It must be noted that the figures for the four cases given iron were omitted from the comparison from the date of starting iron, so that the averages after eight months are thereby slightly raised.) The yolac babies drop from 83 per cent. at five months old to 75 per cent. at ten months old, and thereafter gradually rise to over 80 per cent. The average of all the 267 estimations done between five and eighteen months old on yolac babies not receiving iron was 79.9 per cent., i.e. only about 2 per cent. below the hemolac cases.

Hence replacing 50 per cent. of the milk in the diet with soya bean flour much diminished, but did not entirely prevent, the development of nutritional anaemia. The actual degree of improvement effected by giving yolac cannot be stated, as there was not a simultaneous control series on dried milk without added iron, but, in the author's previous work, a bottle-fed series of infants not getting added iron fell steadily from nearly 76 per cent. haemoglobin at five months old to 69 per cent. by twelve months old (Mackay, 1933).

CALCIFICATION OF BONES. Seventy-six radiographic examinations were made in the late winter or spring months on twenty-six children in the yolac group and thirty children in the control group, aged four months and upwards. In each case the films showed the whole of the forearm bones, the whole of the leg bones and the lower end of the femur. Three children were thought by the author to show some evidence of mild rickets which had already healed, but had left some cupping or irregular calcification at the lower end of the ulna: two of these were control cases and one was a yolac case. The changes were extremely slight in each case (in fact, two of the three considered as rachitic by the author were passed as normal by the radiologist), and, so far as could be ascertained, the babies had had their vitamin emulsion fairly regularly. As in every series of films of babies' bones, minor deviations from the normal were found, i.e. there was sometimes some osteoporosis present and sometimes slight lipping at the lower end of the ulna, but these cases were no more numerous in the yolac group than among the controls. Hence yolac with cod-liver oil proved as satisfactory as dried milk with cod-liver oil from the standpoint of bone calcification.

MORBIDITY RATES. (a) **GENERAL.** In order to compare morbidity rates, illnesses were counted from the babies' weight charts as described in previous papers (Mackay and Goodfellow, 1931). Every infection accompanied by a loss of weight or retardation of gain in weight was counted as an illness. Sometimes such a loss in weight would be missed because weight was regained before the next attendance, but this applies to both groups alike. Every infectious fever and every case of otorrhoea was also counted an illness. The general

morbidity rates are shown in table 8. The total morbidity rate is almost the same in the two groups, but the incidence of infections of the respiratory tract and of the gastro-intestinal tract differs. The yolac cases show an excess over the controls of gastro-intestinal upsets, and controls an excess of respiratory tract infections. Closer examination shows that the chief difference in the group of respiratory infections is that there are fewer cases of bronchitis recorded in the yolac group. A possible explanation is that when suffering from any infection, babies fed on yolac show a greater tendency to loose stools than do those fed on hemolac, and that this may have resulted in some cases of primary bronchitis in the yolac group being classified as enteritis. The total morbidity rate among yolac cases and controls was similar.

TABLE 8

GENERAL MORBIDITY RATE—YOLAC CASES AND CONTROLS COMPARED

	YOLAC CASES		CONTROLS	
No. of infants	48		102	
Average attendance	9 months 12.6 days		8 months 23.6 days	
No. of child-months	452 $\frac{1}{10}$		896 $\frac{7}{13}$	
DISEASE	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS
RESPIRATORY TRACT—				
Cold in head and sore throat ..	50	11.1	110	12.3
Bronchitis	14	3.1	63	7.0
Pneumonia	1	0.2	1	0.1
Otorrhoea	11	2.5	11	1.2
		16.8		20.6
GASTRO-INTESTINAL—				
Diarrhoea and vomiting, or either	34	7.5	43	4.8
OTHER DISEASES—				
Specific fevers	7	1.6	13	1.4
Not otherwise classified	3	0.7	4	0.4
		2.2		1.9
Total	120	26.5	245	27.3

(b) LESIONS AFFECTING SKIN, MOUTH AND EYES. The incidence of lesions of the mouth and eyes (see table 9) is of a similar order in both groups, and in each case the total numbers are small. The total incidence of skin lesions is also similar but there are more infective skin lesions in the yolac group. Among infective skin lesions are classified all napkin area lesions with excoriations or pustules. Table 10 sets forth the incidence of lesions of the napkin area in the two groups of babies. The excess of infective skin lesions in the yolac group is the result of a greater frequency of excoriations and infections of the napkin area in this group, corresponding to the different character of the stools in the two groups.

STOOLS. The stools of the babies in the control groups fed on hemolac tended to be constipated, as is usual with babies fed chiefly on cow's milk. Even in young babies the stools were generally formed, though usually soft ; hard stools, however, were not uncommon. The presence of added iron in

the diet does not increase constipation. The colour was usually dark from the presence of iron—shades of greyish or blackish brown, perhaps with a tinge of green or yellow. The reaction to litmus, when tested (the stool brought to hospital might be one from the previous day), was nearly always alkaline whilst the babies were bottle-fed, but after mixed feeding was started, though alkaline or neutral stools predominated, slightly acid stools were fairly common. The odour was considered in excess of normal, and was offensive to a greater or lesser degree in, perhaps, one case in three. This tendency to offensive stools has been noted before with babies given iron (Mackay and Goodfellow, 1931), and both acid and alkaline stools might be offensive.

TABLE 9
LESIONS OF SKIN, MOUTH AND EYES—YOLAC CASES AND CONTROLS COMPARED

	YOLAC CASES		CONTROLS	
No. of infants	48		102	
Average attendance	9 months 12.6 days		8 months 23.6 days	
No. of child-months	452 $\frac{1}{10}$		896 $\frac{7}{15}$	
LESION	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS
SKIN—				
Infective	103	22.8	149	16.6
Excoriation, pustules, boils, intertrigo, external otitis.		61.1		59.0
Non-infective	173		380	42.4
Erythema, peeling, chapping, papules, sudaminal rashes, urticaria.				
MOUTH—				
Thrush or other stomatitis, ulcer or cracked lip	11	2.4	15	1.7
EYES—				
Conjunctivitis, blepharitis, and styes	7	1.5	15	1.7
Total	294	65.0	559	62.4

TABLE 10
LESIONS OF SKIN OF NAPKIN AREA—YOLAC CASES AND CONTROLS COMPARED

LESION	YOLAC CASES		CONTROLS	
	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS	NO. OF ATTACKS	NO. PER 100 CHILD-MONTHS
Excoriation, excoriated papules, pustules, boils	72	15.9	95	10.6
Erythema, peeling, chapping, papules	61	13.5	109	12.2
		29.4		22.8

The stools of babies given yolac were usually softer, often not formed even in babies over a year old, though formed stools were common. In colour they were generally brown, often tinged with yellow, sometimes tinged with grey or green. The stools were homogeneous. Among those tested, the reaction to litmus was more often acid than in the control group, but an alkaline reaction preponderated. The odour was seldom offensive.

The number of stools passed daily was usually greater among the children fed on yolac. Sometimes a young baby who was doing well might have four or more stools in the day, which was uncommon in the hemolac group. Most commonly in children of both groups there were one or two stools daily, but the number with one stool in the day was distinctly smaller in the yolac group than in the control group, and yolac babies were less troubled with constipation.

URINE. The urine in the control groups was acid in the great majority of specimens tested. In the yolac group an alkaline urine was much more frequent, though after mixed feeding was started it was generally acid. This is in contrast with the alkaline urine of babies fed only on soya flour with added carbohydrate and fat, as described by Mader (1932).

TOLERATION OF FOOD. A large proportion of the babies were first brought to hospital on account of feeding difficulties. The mothers' statements as to excessive crying, fretfulness, vomiting and looseness of stools were recorded. Among the babies included in the comparison, complaints of crying and fretfulness during the first eight weeks of attendance were about equally common in the yolac and control groups, though complaints of loose stools and vomiting were more common in the yolac group. After starting yolac the number of stools often increased, and even in the absence of looseness, mothers might refer to the condition as diarrhoea. If looseness was not present, no change in the food was usually advised. In only one case did the author decide that a baby ought not to be kept on yolac: this baby had frequent small stools, some vomiting and some fullness of the abdomen on yolac, and apparently suffered from colic. After gaining only about $3\frac{1}{2}$ ounces weekly for some weeks on yolac, he was changed by the author's advice on to unmedicated dried milk, with an immediate improvement, i.e. a good gain in weight and cessation of symptoms.

The reasons for stopping attendance may throw some light on the question of toleration. Of the children in the two groups, seventeen in the yolac group and thirty-six in the controls were discharged by the author on account of age or the termination of the investigation; of the rest, thirty-one yolac cases (64.6 per cent.) and sixty-six controls (64.7 per cent.) ceased to attend without being discharged: i.e. the same proportion in each group. In some cases the mother said that she wished to change the food, that the child refused the yolac or hemolac, or that she was not satisfied with the baby's progress. This happened seven times with yolac babies (14.6 per cent.), and eight times with controls (7.8 per cent.). Certainly children of, say, twelve months old and upwards seem to tire more readily of yolac or hemolac than they do of unmedicated dried milk, and it is desirable to vary the taste by giving the food in different combinations.

To summarize, the impression was gained that yolac was less easily tolerated than hemolac ; but that begun gradually (as was always advised, but not always carried out by the mothers in the present investigation), the great majority of babies given yolac tolerated it well and had no colic or discomfort. It should not be given to a baby with a gastro-intestinal upset. A sudden change, contrary to advice, on to either yolac or hemolac certainly caused diarrhoea in some cases. When looseness did develop on either yolac or hemolac, the mother was asked temporarily to stop the feeds and give water only, gradually working back first on to a full feed of unmedicated dried milk and then gradually changing back to yolac or hemolac.

Babies excluded from the final comparisons. The number of cases taken on and the number finally excluded in each group were as follows :

YOLAC GROUP : taken on 80, finally excluded 32 (40 per cent.).

HEMOLAC PLUS COD-LIVER OIL GROUP : taken on 70, finally excluded 21 (30 per cent.).

HEMOLAC PLUS VITAMIN D GROUP : taken on 75, finally excluded 22 (29 per cent.).

In any investigation of this type the wastage of cases which cannot be used in the final comparison is bound to be large, but since the wastage in the yolac group was 40 per cent. and in the controls approximately 30 per cent., it is necessary to consider whether more dropped out of the yolac group because the food was less satisfactory. The analysis of the excluded cases (table 11) shows that whereas a rather smaller proportion dropped out of the yolac group than out of the other groups for reasons believed to be unconnected with the nature of the feeding advised, the number who dropped out because the baby was upset or was thought by the mother to be upset by the food was greater in the yolac group, which certainly suggests that the yolac was less easily tolerated. The hemolac was supplied to mothers at the price of 1s. 6d. per pound, the yolac at 1s. per pound. What psychological effect this had it is difficult to say ; but in some cases mothers whose babies cried probably suspected the 'cheap' and unknown food yolac without sufficient justification. For example, three babies in the yolac group who were gaining well were changed by the mothers on to other foods 'because the baby was crying,' but, according to their subsequent statements, the babies continued to cry after the change. Probably if their babies had received hemolac, a name which many mothers would know, they would not so readily have interpreted the symptoms as indicating the need for a change in the food.

Discussion and conclusions

This investigation has demonstrated that babies can be reared, kept in good health, and grow well on the diet described, in which a soya flour (soyolk) has been used to replace half the milk in artificially fed babies' diets. The control cases, who received hemolac with vitamin additions and sugar, and later on, like the yolac cases, table food in addition, were getting as good a diet as

TABLE 11
 CASES EXCLUDED FROM FINAL COMPARISON

	YOLAC		HEMOLAC AND COD-LIVER OIL		HEMOLAC AND VITAMIN D	
	NO.	PER CENT.	NO.	PER CENT.	NO.	PER CENT.
NO. OF CASES TAKEN ON...	80	—	70	—	75	—
NO. OF CASES FINALLY EXCLUDED	32	40	21	30	22	29
For reasons unconnected with toleration of food—						
For pathological conditions which rendered case unsuitable	2		0		3	
For insufficient or wrong emulsion, or re-establishment of breast feeding	1		4		2	
For reasons probably unconnected with nature of food—						
Treatment under one month—						
1. Infants gaining at rate of 5 oz. and more weekly—		10		11		12
No complaints when last seen	3		1		4	
Intercurrent illness when last seen	—		2		—	
2. Infants gaining less than 5 oz. weekly—						
Cause probably an infection or feeding disturbance present when first seen	4*		4*		3	
For reasons possibly connected with nature of food—						
Treatment under one month—						
1. Infants gaining at rate of 5 oz. or more weekly—complaints of crying, vomiting or diarrhoea	6†		4		1	
2. Infants gaining at less than 5 oz. weekly—no cause found apart from feeding difficulties	9	15	1	5	2	3
Did not re-attend after ordered yolac or hemolac—reason unknown	7	8.8	5	7.1	7	9.3

* 1 died.

† 3 babies were said to cry as much after change of food

the author could devise. The rate of gain in weight of the group of babies getting the mixture (yolac) of soya flour and dried milk was slightly inferior to that of the hemolac group, but perhaps rather better than would be obtained with unmedicated dried milk. The subnormal growth on unmedicated cow's milk is presumably the result of infections associated with iron deficiency. In every country where the subject has been investigated, anaemia in babies

and young children has been found to be common, and everywhere anaemia will predispose to infection and so diminish the rate of gain in weight. The use of yolac produced a fairly satisfactory haemoglobin level in most babies and a morbidity rate as low as produced by the use of hemolac, and hemolac halved the morbidity rate occurring with unmedicated dried milk by abolishing iron deficiency anaemia. The average period during which the babies received yolac without any other source of milk, and without any solid food, was about three-and-a-quarter months, from say two-and-three-quarter months to six months old. It is possible that with more prolonged bottle-feeding on yolac the results might have been less satisfactory. On the other hand, the babies who came under observation early and were on yolac from less than two months old, averaged at six months old 15 pounds 11·6 ounces, that is about 11½ ounces more in body weight than the whole yolac group, so that their record is good. Since various authors have compared the weight curves of babies getting soya flour with Holt's standard, it may be of interest to note that both groups started considerably under Holt's standard (as one would expect, since they were subnormal children brought to hospital for advice), the controls passed above the standard at eight months old, the yolac cases at ten months old, and both remained above it till eighteen months old, after which the numbers are small.

Bone formation, as shown radiographically, is as good on the yolac diet as on dried milk (both groups receiving a vitamin D supplement), hence presumably the calcium-phosphorus ratio is satisfactory. Hard stools, which are so common with most artificially-fed babies, are not common with babies on yolac. The fact that yolac is not quite as easily tolerated as dried milk alone is a definite disadvantage. The author's impression is that yolac did give rise to colic or discomfort in some babies, but that if the change over to yolac was made sufficiently gradually most babies took it easily and without discomfort, and even those who experienced some discomfort at first usually became quickly accustomed to the food and any discomfort ceased. It is possible that boiling the yolac mixture would render it more easily tolerated and reduce the incidence of loose stools, but this could only be settled by another controlled investigation. Boiling was not advised in the present investigation for two reasons: the first was that if the preparation of the food given to one group of babies had been more troublesome and had cost more in fuel than preparing the food given to the controls, this would have introduced complicating factors, which might well have vitiated the comparison, as time and cost would militate against the regular administration of yolac. The second reason was that the simpler the method of preparation, the more likely it was that the mixture could be adopted in tropical countries, or for relief work among war refugees or others in circumstances where simplicity of preparation is important. The yolac and hemolac were both prepared by mixing the powder with water which had been brought to the boil. If the mixture had to be boiled after mixing this might tempt the mother to prepare twenty-four hours' supply at a time, which, in a poor home, is definitely contra-indicated on account of the certain contamination of the food by micro-organisms. It should be noted that in this investigation

if a baby developed diarrhoea neither hemolac nor yolac was given until the stools were normal, unmedicated dried milk being used instead. Moreover, when first seen, babies were habitually changed to unmedicated dried milk as a first step, and from this during another week gradually on to hemolac or yolac.

Wherever, as in London at the present time, dried milk, with or without iron, is obtainable for practically all babies, it is unlikely that yolac will be much used. But where this is not available, there seems every reason for trying to organize the supply of a preparation such as yolac—either imported or prepared from local produce. No doubt there would be many problems of packing and distribution to be solved in a hot climate, but if prepared on a large scale and distributed by some means eliminating retail costs it would seem that the price should be little more than half that possible for dried milk, for soya bean is cheap. Used in a hot climate by ignorant mothers the problem of diarrhoea may prove difficult, but nevertheless this mixture should be the means of saving many lives now lost through the want of any good substitute for breast milk. If the change to yolac has to be made suddenly, this could be done safely by starting the baby on a small amount, i.e. underfeeding at first and increasing gradually up to the baby's full needs. It was commonly said in London not many years ago that poor mothers would not learn to measure and mix dried milk, but events have proved this false. Since, the world over, women prepare and cook food, there seems no reason why the mothers of Africa or Asia should not learn to mix a milk-soya-bean powder with hot water.

In most tropical countries there should be no need to give vitamin D with yolac, and vitamin C could presumably be supplied without much difficulty from fresh fruit or vegetable juice. The vitamin A value of soya bean is said to be of the same order as that of average cow's milk (reckoned on dry weight), and there is no gross deficiency of vitamin A in average dairy milk, though its vitamin A value is much less than that of human milk (Dann, 1936 ; Meulemans and de Haas, 1938). The addition of vitamin A would increase the cost, so presumably where the element of cost is decisive any vitamin A addition would be omitted. The quantity of vitamin B complex, so far as evidence is available, should also be adequate.

Only one mixture of dried milk and soya bean has been tried out in this work. The obvious question arises whether, if this mixture cannot be produced at a low enough price to meet the economic circumstances of a country, any further modification could render it cheaper and still adequate, pending the time when cow's milk in some form will be available for all who may require it. It is possible that one of the following modifications might prove as satisfactory : soya flour with a half-cream dried milk, or even with skimmed milk, and a larger proportion of sugar than was used by the author, or a mixture containing more than 50 per cent. soya flour. With the findings here recorded, and those of Rittinger and his associates, which prove that the use of a soya-bean-cow's-milk mixture as an infant's food is justified by its results, it is hoped that others will try out this or other modifications where the problem of milk shortage is acute.

For older children and even adults the mixture should also prove useful, though here certain additional facts must be borne in mind. The inclusion of say three-quarters to one pint of milk, full-cream or even skimmed, improves the growth and well-being of schoolchildren of the working classes in this country (Leighton and Clark, 1929). This is proven, and is true for other countries also. It is generally agreed that the full-cream milk supplement is effective because it is fitted to meet any deficiency, except iron, in greater or less degree, and the deficiencies in one child's diet will not necessarily be the same as those of his next door neighbour, let alone those of another child in another continent. Soya bean, on the other hand, in spite of its valuable constituents, may not make good some of the deficiencies common in the area ; for example, Aykroyd and Krishnan (1937) found that a supplement of soya bean did not render the diets of school-children in Southern India satisfactory. Hence if asked whether, in such circumstances, a supplement of one pint of milk daily or of half a pint of milk with an equivalent number of calories in soya bean should be chosen, evidence favours the pint of milk, but the second, nevertheless, would probably prove a good second best. The insipid taste of yolac is definitely unattractive, but it has no objectionable taste and it can easily be used in combination with other foodstuffs, cooked or uncooked. If yolac is mixed in bulk for groups of children, the rapidity with which the soya flour begins to sink to the bottom would be a definite difficulty, but one which could probably be overcome, e.g. by cooking.

It is desirable to ascertain that the soya flour is prepared and packed under proper hygienic conditions, since it may otherwise contain many organisms, including spore-bearers.

Summary

This paper is concerned with the efficacy of a cheap substitute for breast milk, in the form of a soya flour with dried milk powder. The composition, nutritive value and uses of soya bean flours for infant feeding, as described chiefly by American and Chinese writers, are discussed.

The author's work is a comparison of the progress made by two groups of babies living in their own homes and attending the Queen's Hospital for Children in London. The first group received till six months old a mixture (yolac) of equal parts of full cream roller process dried milk and a soya bean flour, prepared by a modification of the Berczeller process, together with a supplement of cod-liver oil ; the controls received dried milk with added iron (hemolac), and a supplement of cod-liver oil or vitamin D emulsion. Both received orange juice. After six months old the babies were given a mixed diet, the first group continuing to have yolac, about one to one-and-a-quarter pounds weekly, the second the same amount of hemolac, providing them with about one pint of milk daily.

The observation lasted from July, 1935, to March, 1938, and 48 'yolac babies' and 102 controls are included in the final analysis. The average age at the first attendance was the same to a day, i.e. 2 months 8 days ; the average

weight differed by about 1 ounce, and was a little over 9 pounds. The average period of attendance was 9 months 13 days and 8 months 24 days respectively.

Both groups made good progress ; the average weekly gain in weight of the controls (4.3 oz.) was slightly superior to that of the yolac cases (3.98 oz.), the difference being about $1\frac{1}{2}$ ounces per month. The average weight curve of the controls was superior to that of the yolac cases from about six months onwards ; the difference in weight at six months is about 13 ounces, and at twelve months about 2 ounces. Since the difference was small the determination of whether or not it was statistically significant seemed of small practical importance, and as the period of attendance varied the determination would be laborious and was therefore omitted.

The babies in the yolac group for the most part showed a satisfactory haemoglobin level, but four babies dropped to 60 per cent. haemoglobin or less, and these were treated with iron. The average haemoglobin level from five to eighteen months old of the babies in the yolac group was about 80 per cent., or about 2 per cent. lower than the average of the hemolac group, but it was higher for the whole of this period than would be found in babies fed on un-medicated dried milk.

The total morbidity rate of the yolac group was about the same as that of the controls, and therefore better than would be expected with babies fed on milk without added iron. On the other hand the tendency to loose stools was greater in the yolac group. Calcification of the bones was as good in the yolac group as in the control group.

Yolac is not as easily tolerated as full cream dried milk, and should be started gradually : so started it is, with a few exceptions, well tolerated, though in some cases it appears to give rise to some abdominal discomfort at first. If it is impossible to make the change from the existing feed gradually, yolac should be given in very small quantities at first, taking about a week to get the baby on to its full calorie requirements.

A mixture of equal parts of dried milk and soya bean flour, such as used in this investigation, provides an infant food on which babies make good progress. It should be possible to market it at a price much lower than that of full-cream dried milk, and it is suggested that owing to its relative cheapness it merits extended trial in countries where, for economic reasons, a satisfactory substitute for breast milk has hitherto been unobtainable.

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