STAPHYLOCOCCAL FOOD POISONING ASSOCIATED WITH SPRAY-DRIED MILK

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Since the expansion of the School Meals Service at the outbreak of war in 1939, milk powder, supplied through the Ministry of Food Pool, has served as a valuable component of school dinners and has been regarded as 'safe'. Until 1953 no outbreaks of staphylococcal food-poisoning attributed to dried milk had been reported in England and Wales. During June and July 1953 eight explosive outbreaks occurred in school canteens in England. There was strong circumstantial evidence that dried skim milk powder was the vehicle of infection in each case.

The first four outbreaks occurred between 26 June and 10 July in the Surrey area and were investigated by us. Three more occurred between 15 July and 24 July in the London area; for details of these we are indebted to Dr J. A. Scott, Medical Officer of Health, London County Council. In all these seven outbreaks the incriminated milk powder came from a common source. A further outbreak occurred on 10 September, in Yorkshire, but the spray-dried milk came from a different source. Dr D. D. Payne, Divisional Medical Officer of Health, kindly provided relevant information.

THE OUTBREAKS

On 26 June 1953, the first outbreak occurred in five schools served from a central kitchen. Altogether 991 meals were served, and 3–4 hr. later at least 118 of the pupils and staff were affected. No sufferers required admission to hospital and few sought medical aid. On careful questioning it transpired that no one who had eaten the first course only had been affected but that all sufferers had partaken of the second course, which consisted of butterscotch flan and artificial cream. The cream had been prepared as a cold mix from dried skim milk powder, water and sugar, 3 hr. before the meal.

Some 'left-over' food was recovered from the swill bin but this did not include any cream. No organisms of the food poisoning groups were isolated, but the remains of the milk powder which had been incorporated in the cream gave a scanty growth of *Staphylococcus aureus*, later shown to belong to phage type 42E/53W. (The phage patterns of the staphylococci from these and the other outbreaks were complex and difficult to interpret; they seemed, nevertheless, to be merely variants of a single pattern which is, for convenience, referred to as 42E/53W.) In this and subsequent outbreaks, no significant findings were obtained from the routine examination of food handlers' nose and throat swabs and faeces. *Staph. aureus* was

isolated once from the vomit and several times from the faeces of patients, but in no instance did the strain belong to phage type 42E/53W.

On 8 July, 45 persons, including 41 pupils and 4 adults, were taken ill after a meal consumed by 203. Again only those who had consumed the second course were affected. This consisted of an iced sponge with a layer of artificial cream prepared as a cold mix from skim milk powder, margarine, castor sugar and water. The only food available for examination was the cream and some of the dried milk used in its preparation. *Staph. aureus* belonging to phage type 42E/53W was isolated both from the cream and from the dried milk.

An interesting feature of this outbreak was that the cook was found to have a septic finger from which a staphylococcus of identical phage type was isolated. It seemed reasonable to suppose that she had infected the dried milk and cream, but later the isolation of staphylococci of similar phage pattern from freshly opened tins of dried milk suggested that the cook's fingers might have been infected from the milk powder.

In the third outbreak, on 9 July, out of a total of 353, no less than 190 pupils and several members of the teaching staff were affected. This outbreak was of a more violent type, medical aid was sought and two patients required admission to hospital. The food responsible was artificial cream made from the same recipe and eaten with dates. Left-over cream did not yield any pathogenic organisms but the milk powder used in its preparation gave *Staph. aureus*, phage type 42E/53W.

The fourth Surrey outbreak involved seven schools served from a central kitchen. Out of a total of 732 who had the school dinner 339 were affected. The offending food-stuff which all the patients had consumed proved to be a trifle, served with artificial cream prepared as a cold mix. The investigation of this outbreak was made easier because it was the custom in this canteen to refrigerate for the 24 hours following a meal samples of all the food eaten. *Staph. aureus*, phage type 42E/53W, was isolated both from the cream and from the dried milk used in its preparation.

The epidemiological and laboratory investigation of these four outbreaks strongly suggested that spray-dried skim milk was the common source of infection. On the advice of the County Medical Officer, the Education Committee, pending further investigation, prohibited the use of dried milk in all Surrey school canteens. On withdrawal of the milk powder no further outbreaks occurred in Surrey.

The epidemiological features of the three outbreaks in London conformed to a similar pattern. The numbers affected were 132, 99 and 147 respectively. In one outbreak the article of food responsible was a chocolate spread incorporating dried milk and not subjected to heat; in the other two the vehicle was artificial cream. In all instances the cold mix, containing dried milk, was prepared 3–4 hr. before consumption. *Staph. aureus*, phage type 42E/53W, was isolated from the dried milk used in all three outbreaks.

When the use of certain brands of dried milk was prohibited in all London County Council feeding centres, no further outbreaks occurred.

An outbreak occurred in Yorkshire on 10 September 1953, and was apparently unconnected with the preceding outbreaks. The vehicle of infection was a custard

prepared and cooked in the usual way. An hour later milk freshly constituted from dried milk powder was added to the custard which was not reheated. The custard was consumed about an hour later.

After withdrawal of the particular brand of dried milk used, no further outbreaks occurred.

CLINICAL FEATURES

After a symptomless interval of 3–4 hr., a feeling of nausea and general malaise ushered in a sudden attack of vomiting which tended to recur in bouts over the next few hours. Diarrhoea occurred in about one-quarter of the cases. Headache was not a feature. Some patients complained of cramps in the limbs and of severe abdominal pain. Many were apprehensive and collapsed. The pulse was rapid and of poor volume and the temperature subnormal. Severe cyanosis was noted in three of the hospital patients. Rapid recovery, even from a state of collapse, followed in from 3 to 24 hr.

BACTERIOLOGICAL EXAMINATION OF SPRAY-DRIED SKIM MILK POWDER

At the instigation of the Ministry of Food a bacteriological survey of samples of the milk powder from the same source as the dried milk incriminated in seven of the outbreaks was carried out in several laboratories, all of which used similar media and technique. We are indebted to Mr C. L. Heller of the Ministry of Food, and to Dr Betty Hobbs and Dr A. J. H. Tomlinson of the Public Health Laboratory Service (Medical Research Council) for permission to include their results, together with those obtained by one of us (D. M. S.)

The milk powder in question was supplied in 21 lb. tins, each tin bearing a code number to indicate the date of manufacture and the batch number. A batch consisted of twenty tins. It was significant that the tins responsible for the outbreaks had all been processed on 9 and 10 May 1953, and that all belonged to batches processed late in the day's run.

Only a limited number of tins processed before 9 May was available for this survey; most had already been used and without apparent ill effects. Plate counts of the general organisms present and of coagulase-positive *Staph. aureus* were carried out on twenty-one samples of milk powder processed in April and in early May. All samples yielded low plate counts and *Staph. aureus* was absent from 1 g. of milk powder. The bacteriological results from 6 to 12 May are shown in Table 1. These indicate that from 8 May the bacterial content of the powder showed a sudden and very marked rise and that *Staph. aureus* began to appear in considerable numbers. In addition, the 'normal' increase in bacterial count during the run of the plant became greatly exaggerated. On 11 May the counts returned to normal, but further samples taken later in the month, with few exceptions, showed consistently high counts both of general organisms and of *Staph. aureus*. In June and July results became more varied, samples yielding good results for several days running and then showing a dramatic rise both in general and in staphylococcal counts. No further samples were available as production had necessarily ceased.

Table 1. *Results of bacteriological examination of samples of milk powder processed between 6 and 12 May 1953*

Date of manufacture	Batch no.	General plate count per gram	*Staph. aureus* plate count per gram
6 May 1953	4	15,000	Absent
	38	75,000	Absent
	48	430,000	Absent
8 May 1953	10	2,000	Absent
	26	44,500	Absent
	54	600,000	100
9 May 1953	4	175,000	Absent
	59	10,000,000	45,000
	78	20,000,000	500,000
10 May 1953	7	128,000	Absent
	53	50,000	10,000
	76	9,000,000	2,750,000
11 May 1953	2	114,000	Absent
	13	500	Absent
	15	1,800	Absent
12 May 1953	2	34,000	Absent
	69	354,000	1,000
	86	190,000	Absent

Only a small number of the results obtained have been shown but they are a representative sample.

Table 2. *General plate counts on dried milk*

Plate count/g.	Roller-dried milk	Spray-dried milk excluding manufacturers A and B	Spray-dried milk manufacturer A	Spray-dried milk manufacturer B
Under 1000	120 (76·44 %)	6 (5·61 %)	8 (8·90 %)	0
1000–10,000	28 (17·83 %)	22 (20·56 %)	21 (23·33 %)	3 (3·03 %)
10,000–100,000	9 (5·73 %)	53 (49·53 %)	22 (24·44 %)	69 (69·70 %)
1 million	0	18 (16·82 %)	21 (23·33 %)	22 (22·22 %)
More than 1 million	0	8 (7·48 %)	18 (20·00 %)	5 (5·05 %)
Total samples	157	107	90	99

In view of the high bacterial counts and the large numbers of staphylococci found in the brands of milk associated with these outbreaks, it seemed desirable to find out whether or not this was a normal picture of the bacteriology of spray-dried milk. With the help of the Ministry of Food and local sampling officers, a number of samples were obtained for examination. The results are shown in Tables 2 and 3. Manufacturer A processed the dried milk associated with the Surrey and London outbreaks, Manufacturer B that associated with the Yorkshire outbreak. Included for comparison were 157 samples of spray-dried milk from other manufacturers and 107 samples of roller-dried milk from manufacturers including A and B. Because the milk powder had been processed before the occurrence of these outbreaks the manufacturers could have taken no precautions designed to improve the bacteriological quality of their product.

It will be seen that as far as the general bacterial count is concerned the results obtained from different manufacturers of spray-dried milk are not grossly dissimilar, but that the products of manufacturers A and B differ from the others in that a higher proportion of samples contain *Staph. aureus*, sometimes in very large numbers. The results of manufacturer A may perhaps be slightly biased by the inclusion of an undue proportion of samples prepared on 9 and 10 May. The majority of the staphylococci isolated from these samples gave phage type patterns similar to those from the samples of milk associated with food-poisoning. On occasion, however, strains of different phage type were isolated and it was noticed that these strains tended to occur in runs over several days, often with gaps in between.

Table 3. Staphylococcus aureus *plate counts on dried milk*

Staph. aureus/g.	Roller-dried milk	Spray-dried milk excluding manufacturers A and B	Spray-dried milk manufacturer A	Spray-dried milk manufacturer B
0	157 (100%)	81 (75·70 %)	27 (30·00 %)	65 (65·66 %)
Under 1000	—	17 (15·90 %)	17 (18·90 %)	20 (20·20 %)
1000–10,000	—	7 (6·54 %)	14 (15·55 %)	6 (6·06 %)
10,000–100,000	—	1 (0·93 %)	18 (20·00 %)	2 (2·02 %)
100,000–1 million	—	—	11 (12·22 %)	6 (6·06 %)
Over 1 million	—	1 (0·93 %)	3 (3·33 %)	—
Total samples	157	107	90	99

Although it was customary for a build-up in the general bacterial count to occur during the day's run, this was not invariable. As a rule, samples taken early in the day's run had low counts, while those at the end of the run might have either high or low counts. Clearly, the length of the run was not the sole factor in the build-up of the bacterial content.

BIOLOGICAL EXPERIMENTS

In the outbreaks described the period between the preparation and consumption of the food responsible was never more than 3–4 hr., and in some instances only 1–2 hr. That this period is not long enough to permit multiplication of staphylococci was confirmed by the experimental findings of two laboratories, working independently. In each case dried milk from an incriminated batch was reconstituted according to the usual canteen recipe for artificial cream. General and staphylococcal plate counts were made on the cream, which was then set aside at room temperature and at 37° C. for 24 hr., re-counts being made at intervals. No increase in the general count or staphylococcal count occurred within 4 hr.; in certain cases a decrease occurred but this was within the limit of technical error. Only after a time lag of 6–7 hr. did multiplication begin.

These results suggested that the toxin responsible for the outbreaks and present in the reconstituted milk must have been preformed and present in the sealed tins. Naturally we were anxious to demonstrate the presence of this toxin by biological methods, but so far no satisfactory tests for the presence of staphylococcal enterotoxin have been devised. Fulton (1943) showed that the kitten vomiting test,

until then accepted as specific for staphylococcal enterotoxin, was due either to the β toxin or to non-specific irritation. Human beings and monkeys are fairly susceptible but for such a purpose are naturally limited in supply. Only a few experiments could therefore be carried out.

The dried milk used in the canteens for making the synthetic cream responsible for the outbreaks was not available in appreciable quantities. This was due to the fact that large canteens generally use a whole tin for one batch of cream. Smaller canteens may use only half a tin but, in two instances in which this occurred, it was the second half of the tin which was reconstituted for the cream, the first half of the contents having been used the previous day for a cooked product, which gave rise to no ill effects.

For the purpose of these experiments several dried milks were selected which had been processed at the factory concerned on 9 and 10 May, and which were known to contain large numbers of *Staph. aureus* of phage type 42E/53W. Milk was reconstituted from these and the equivalent of 10 g. of milk powder was drunk by each of seven human volunteers. No ill effects ensued. Cream was prepared from the same powder, allowed to stand 3–4 hr. at room temperature, and then consumed by five human volunteers and four monkeys. Again no ill effects occurred. Even allowing for the varying susceptibilities of human beings and of monkeys to stapylococcal food-poisoning, these results were unexpected and disappointing.

PRODUCTION OF SPRAY-DRIED MILK POWDER

Firms which manufacture spray-dried milk powder derive their raw milk supply from some thousands of farms situated at varying distances from the factory. An aggregate of the morning milkings and those of the previous evening are delivered to the dairy, usually in the early afternoon. The supply may include milk transported by road tanker as surplus from other dairies. The keeping quality of the milk is determined before use by the resazurin test. The spray-drying season normally lasts from April to August.

The methods used in processing vary from firm to firm but the following stages are usually included:

(1) Flash heating to 170° F.

(2) Rapid cooling to 110° F.. the optimum temperature for operation of the separator.

(3) Cooling to 40° F. and storage in a lagged tank.

(4) Pasteurization. The separated milk is passed through pre-heaters, held at 140° F. for 10 min. and then at 175° F. for 10 sec.

(5) Evaporation of the skim milk until the total solids are between 40 and 45 %.

(6) Passage through the atomizer feed tank. (Balance tank.)

(7) Spray-drying. The condensed milk is forced as a fine spray into the drying chamber through which passes a continuous stream of air at 310–320° F.

These operations are automatic and do not involve handling of the milk powder, but the adjustment of the weight of powder in the tins and the affixing of the lid is carried out by hand.

Cleansing of spray-drying plants takes place after each day's run, washing in cold water being followed by the use of a detergent solution and then by steam or high velocity hypochlorite solution. Road tankers and milk churns are cleansed in a similar manner.

IMPORTANCE OF ADEQUATE PLANT CLEANSING

The production of milk powder of high bacteriological quality is related to adequate plant cleansing. Nichols (1939) found that the bacteriological quality of spray-dried milk usually deteriorated during a continuous day's run. Crossley & Johnson (1942) found that an increase in the bacteriological content of spray-dried milk became pronounced after 10 hr. and recommended a break for plant cleansing every 7–9 hr. Perfunctory plant cleansing was followed by high bacterial counts.

In a personal communication Dr Betty Hobbs and Mr H. B. Hawley have provided details of counts made on raw milks and on milk at various stages of processing in a plant similar to that which produced the spray-dried milk concerned in the outbreaks. Of six samples of raw milk examined, counts varied from approximately 3000 to 35 million per ml. and the staphylococcal count from less than 250 to 2500 per ml. In every instance coagulase-positive staphylococci were isolated by means of a 10% salt meat medium. The bacteriophage types of these strains varied slightly, but the pattern usually included lysis by some or all of the following phage filtrates, 29/52/52A/6/7/47/42E/53/54/73.

This bears out the findings of Williams (1941), who stated that milk drawn aseptically from individual cows of each of ten herds showed that 50% of animals were shedders of staphylococci and that 43% of the samples gave *Staph. aureus*, and this in the absence of any signs of mastitis. It is obvious, therefore, that all bulked milk reaching a processing plant will contain staphylococci, probably of a coagulase-positive variety and frequently belonging to one of the types capable of producing food-poisoning.

Samples were taken from a spray-drying plant after several hours' continuous run. Milk from the brine-cooled storage tank, i.e. before processing, gave a colony count of more than 10 million per ml. with more than 10,000 per ml. of coagulase-positive staphylococci. After heat-treatment and evaporation a sample from the seal-pot (through which the milk passes on its way to the balance tank) yielded less than 100 colonies per g. with no demonstrable cocci. The next sample, taken from the balance tank ('atomizer feed tank') where the concentrated milk is held before it is finally dried, showed a dramatic rise in bacterial count. The colony count was more than 100 million per g. with approximately 5 million per g. of coagulase-positive staphylococci of a phage type different from that of the strains isolated from the raw milk. In the final process of spray-drying the colony count was reduced to less than 10,000 per g. A proportion of coagulase-positive staphylococci remained, their phage type being the same as that of the strains from the balance tank. On another occasion the colony count rose from under 1000 per g. in the seal pot sample to 20,000 per g. in the balance tank. Coagulase-positive staphylococci, although absent from the seal-pot sample, were isolated from the balance tank.

It seemed that the lower layers of evaporated milk in the balance tank might form a static deposit or sludge which could build up a high bacterial contamination; this might be passed on to the evaporated milk flowing slowly through the tank.

After routine cleansing of the plant at the beginning of a new run, the initial colony count of the milk was reduced to less than 100 per g. by pre-heating and evaporation. A sample collected from the atomizer feed tank still retained this low count and the samples of dried milk after this run showed no evidence of coagulase-positive staphylococci.

This work confirms the finding that spray-drying cannot be relied on completely to destroy all viable pathogens (Crossley & Johnson, 1942), but suggests that it comes very close to this ideal given perfect cleansing of the plant. It also demonstrates that re-infection of the pasteurized and evaporated milk may occur in the 'atomizer feed tank', that is to say, before it reaches the spray-drying chamber.

In collaboration with the Association of Manufacturers the Ministry of Food drew up a code of practice 'designed to safeguard the bacteriological quality of products as distributed for human consumption'. The code lays down stringent regulations regarding optimum temperatures used and their control, the efficient cleansing of the plant and its sterilization, avoidance of contamination subsequent to cleansing, and the regular bacteriological examination of the finished product before it is put into supply.

DISCUSSION

Food poisoning due to staphylococcal enterotoxin is of sudden onset and short duration. The symptoms seldom last more than 24 hr. In mild outbreaks medical aid may not be summoned and, even in severe attacks, before investigation can be begun food remnants will have been discarded and patients so far recovered that they are unable or unwilling to provide specimens. Here we must often rely on circumstantial evidence for diagnosis. In the series of outbreaks described the incubation period, the explosive onset, and the clinical features were typical of those found in staphylococcal food poisoning. The canteens concerned were situated in widely separated districts and the only common factor was their use of the same brand of spray-dried milk powder. In all cases the incriminated meal included synthetic cream or a similar preparation, made with this milk powder and not subsequently subjected to heat. Examination of the milk powder and, where possible, the food prepared from it gave very high counts of *Staph. aureus* of a phage pattern similar to that encountered in food poisoning. Withdrawal of the milk powder was followed by cessation of outbreaks. In face of this evidence it seems reasonable to assume that the outbreaks were due to staphylococcal enterotoxin, and that the source of the enterotoxin was the dried milk powder in use.

Investigation of numerous outbreaks of food poisoning caused by staphylococcal enterotoxin has shown that the circumstances have invariably been such as to favour the multiplication of the staphylococci in the foods prior to consumption (Topley & Wilson, 1946). After the food becomes infected a considerable period, probably 15–24 hr., must elapse to allow this multiplication, which is accompanied

by a 'build-up' of sufficient enterotoxin to render the food poisonous. In the outbreaks under consideration it has been shown that the interval between the preparation and consumption of the food involved was sometimes only an hour and never sufficiently long for multiplication of staphylococci and the elaboration of enterotoxin to occur. The assumption was, therefore, made that the dried milk powder itself contained enterotoxin produced during the processing.

Biological tests undertaken to prove this point were inconclusive. Both reconstituted and synthetic cream made from it failed to produce symptoms in human volunteers and monkeys. It must be borne in mind, however, that the dried milk tested was not from the same tins as those used for the incriminated foods, that individual susceptibility is very variable and that the amount of dried milk powder consumed by volunteers was probably much less than that eaten by most of the sufferers from food poisoning. Although *Staph. aureus* was present in large numbers in the milk powder used, this did not guarantee the presence of preformed toxin. Toxic samples concerned in the outbreaks contained very varying numbers of staphylococci, one having only 45,000 per g. and others between 1 and 10 million per g. In addition, many milk samples containing staphylococci were apparently consumed without producing toxic effects.

The formation of enterotoxin during the production of spray-dried milk is likely to occur at two stages.

(1) *Before the milk has received heat-treatment*

Although outbreaks of staphylococcal food poisoning due to raw milk are uncommon, several well-authenticated outbreaks have occurred, including the original one described by Barber (1914). Outbreaks of this nature have usually occurred when milk containing staphylococci has been allowed to stand for some hours at high atmospheric temperatures. Staphylococcal enterotoxin is thermostable, requiring a temperature of 100° C over a considerable period for its complete destruction. Thus toxin formed in the raw milk would not necessarily be destroyed by the temperature reached in the processing and might well be present in the final product.

(2) *After pre-heating and evaporation of the milk and before spray-drying*

The pre-heating and pasteurization which occur during the initial stages of processing, provided the correct temperatures are maintained, destroy the pathogenic staphylococci along with the other heat-labile bacteria. Milk reaching the balance tank, as shown by samples taken from the seal pot, yields comparatively low general counts and is usually free from staphylococci. During passage through the balance tank it has been found that re-infection of the milk occurs, often with a staphylococcus of a phage type different from that of the strain present in the original milk. Any delay at this stage will permit multiplication of organisms, and, in the case of staphylococci, elaboration of enterotoxin. Such toxin will certainly survive the heat in the spray-drying chamber, which allows viable staphylococci to reach the final product.

The dried milk concerned in the outbreaks under consideration was processed early in May, at which time milk production is approaching its seasonal maximum. and very considerable quantities are diverted to spray-drying plants. The atmospheric temperature was then high and there was every opportunity for the multiplication of staphylococci in the raw milk both before delivery and while awaiting processing. It should be pointed out, however, that no cases of illness were reported as a result of the consumption of cream separated from the milk processed during this period.

When a plant is working to capacity the day's run must inevitably exceed the period of 10 hr., recommended by Crossley & Johnson (1942), at the end of which plant cleansing is essential if the dried milk powder is to maintain a satisfactory bacterial standard. Passage through the balance tank is also prolonged, encouraging the accumulation of a static sludge, the multiplication in this of staphylococci and other organisms, and the consequent re-infection of the evaporated milk held in the tank. Toxin produced at this stage would certainly survive the mild heat o the spray-drying chamber, which permitted viable staphylococci to reach the final product. The very presence of these staphylococci supports the view that infection of the dried milk powder had its origin in the balance tank and that this is a potential source of danger in spray-drying plants.

Precautions now being taken to ensure a safe product are rightly directed towards careful cleansing of plant and avoidance of delay in processing. In particular, the provision of alternative balance tanks which can be put out of action and cleansed at frequent intervals would appear to be a necessity. The ultimate safeguard, however, is to examine by reliable bacteriological methods the dried milk produced each day and to release for human consumption only that which reaches a satisfactory standard of purity.

SUMMARY

Eight explosive outbreaks of food poisoning, occurring in school canteens in England during 1953 and affecting 1190 known cases, are described. The clinical features were characteristic of the toxin type of illness. No deaths occurred.

The food causing all of these outbreaks was prepared from spray-dried skim milk powder. It was not subsequently heat-treated and was usually consumed 3–4 hr. after preparation.

The spray-dried milk powder proved to contain a high content of bacteria, including large numbers of *Staph. aureus*, of a phage pattern often associated with food poisoning. The assumption was therefore made that these outbreaks were caused by staphylococcal enterotoxin.

Because the food was often consumed within 3–4 hr. of reconstitution of the milk powder—before, in fact, the staphylococci had had time to grow—it is concluded that the poisoning must have been due mainly to pre-formed toxin.

Consideration is given to the opportunities for the formation of toxin in a spray-drying plant, and reasons are brought forward for believing that it is formed mainly in the balance tank where the warm milk is kept, sometimes for several hours, before passing into the final drying chamber.

The processing of the milk and the precautions for preventing contamination of the finished product are discussed.

Our thanks are due to Dr K. A. Soutar, County Medical Officer, for permission to publish this article, and to Dr Rosetta Hill, Medical Officer of Health for Barnes, Dr C. Ive, Medical Officer of Health for Epsom and Ewell, and Dr E. J. MacIntyre, Medical Officer of Health for Sutton and Cheam and Banstead, and to their sanitary inspectors, for their assistance with the field investigations.

We acknowledge gratefully the help of Dr R. E. O. Williams, Central Public Health Laboratory, Colindale, who carried out the phage typing of the staphylococcal strains, and that of Mr C. L. Heller of the Ministry of Food, Dr A. J. H. Tomlinson of the Public Health Laboratory Service and Dr Betty Hobbs, of the Central Public Health Laboratory, Colindale, who have allowed us to incorporate certain of their results in this paper. Dr. Hobbs has also given us invaluable advice and assistance throughout.

Finally we owe a great deal to Messrs Aplin and Barrett Ltd., who have provided facilities for investigation into the working of a spray-drying plant similar to that used by the firm which produced the dried milk responsible for the outbreaks described.

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(*MS. received for publication* 20. v. 55)