PROCEEDINGS OF THE NUTRITION SOCIETY

VOL. 2, Nos. 3 and 4 1944

FOURTEENTH SCIENTIFIC MEETING—EIGHTH ENGLISH MEETING

JOINT MEETING WITH THE FOOD GROUP OF THE SOCIETY OF CHEMICAL INDUSTRY

LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE,
JULY 3RD, 1943

MILK

Chairman, Professor H. D. KAY

Professor H. D. Kay (National Institute for Research in Dairying, University of Reading): The subject of discussion today is "Milk," without adjective or qualifying clause. It is to be dealt with from three different angles, each of them broad enough in all conscience, but even taken together they do not by any means cover the immense, I nearly said galactic, field. The present and future of milk are of the first importance for us all, as consumers, and for our greatest national industry, agriculture. For the future of national nutrition is bound up with milk production; the future of milk production is in a very real way the future of British farming.

When milk is discussed before The Nutrition Society and the Food Group, it can be assumed that it will be discussed, in the main, as a human foodstuff, a key foodstuff. It is only recently that the dairy industry itself has begun to look on milk from this point of view. That it may be a food of real importance in winning the war has struck many in all branches of the industry with the freshness of a new idea. Milk producers have for years been so intent on regarding milk as a mere commodity that even today one is looked upon as rather a crank, or at least an anti-Friesian, if one hints that milk may be caused to vary considerably in food value by changes in dairy husbandry, and that the general improvement of the nutritive value of milk is one of agriculture's next tasks. Introductory remarks should not steal the thunder of subsequent speakers, but I hope Dr. Kon will forgive my emphasizing that the average nutritive value of the milk now on the market, particularly in winter, leaves a good deal to be desired. Quantity, especially of winter milk, is of course the great desideratum in war time, but I sincerely hope that The Nutrition Society and the Food Group will make it their

business to see that the nutritional *quality* of milk, particularly that of winter and early spring milk, consumed when other foodstuffs are usually at their nadir of nutritional value, is not forgotten in the drive for quantity.

Milk concerns The Nutrition Society twice over, in the nutritional quality of the milk itself, and in the feeding of the cow for successful lactation. I hope that someone taking part in the discussion will outline the difficulties facing the farmer who, in war time, decides to improve his winter milk output against the severe handicap to his cows of excess of bulk and indigestible fibre in home produced feeding stuffs and even in the national compound cattle foods, where sheer necessity has forced down the starch equivalent to 60 or even less. At the present time, unless the greatest care is taken in cropping and harvesting, in, for example, cutting hay quite early or making silage of really young grass, the average cow cannot get enough energy in winter from the bulk she can consume, to sustain for long a yield of more than about $2\frac{1}{2}$ or 3 gallons a day. Hence her *total* yield is almost certain to go down, unless of course she is a poor animal to begin with and never reaches this level. If further and very desirable increases are to be obtained in our *winter* milk output, the only possible solution with present war time feeding stuffs is to increase the number of dairy cows.

It is probably clear to all here that, for the first time in our history, a comprehensive Government milk policy, in which the three Ministries of Food, Health and Agriculture are collaborating, is now being carried out, based on the key position of milk in the war time dietary. Mr. Davies will doubtless deal with this most interesting phenomenon, embracing as it does five or six different but reasonably well interlocking schemes, which together have so far shown not only prospects of success but real evidence of it. This socially most valuable collaboration must continue after the war not merely as regards milk, but to cover the planned and controlled supply of all essential human foods.

It is common knowledge, and especially welcome knowledge to all members of our two Societies, that our yearly *liquid* milk intake has increased by about 40 per cent. during the last three years. Actually this is a continuation of a tendency which began well before the outbreak of war. During 1938, for example, consumption of liquid milk per head rose, according to available figures, by 11 per cent. From the standpoint of the two Societies here today the important thing is to make sure that this steady rate of progress is not diminished in immediate post-war years. A regular yearly increase in total milk production of 10 per cent. is about as much as dairy farming can hope to achieve, though it is the increase in *winter* milk production that is primarily required, even if the production of summer milk decreased somewhat. From the dairy industry's standpoint, the hoped for increase in *total* milk consumption will encounter the fact, and it seems that it is a fact and not merely a dubious extrapolation from known data, that whatever happens to the birth rate in the immediate post-war years, it is inevitable that the proportion of children to older people will diminish for a generation at least. It is even stated on good authority that the statistical basis for this is so convincing that a firm making baby carriages turned over just before the war to making bicycles and mechanized bath chairs!

There was in fact considerable stirring in the world of dairying and dairy science just before the war, apart from this slow increase in milk consumption. Developments which have made great strides during the war actually began in many cases before it. Thus, assistance from the Government for the production of cleaner and safer milk began some years before the war; certain developments in dairy education began shortly before the war but, in this case, the war very seriously checked progress. The first chair of dairying in any university in Great Britain was established at Reading during 1938, and the Imperial Bureau of Dairy Science was established in the same year. After some years of both State parsimony and trade indifference, dairy research obtained increased financial support through the good offices of the Milk Marketing Board in 1936 and, from private, supplemented by State sources, obtained increased physical facilities early in 1939.

Since the war, and apart from the starting of the Government schemes, two definite milestones of progress having an important relationship to milk, have been the foundation of The Nutrition Society in 1941 and the very recent establishment of the Society of Dairy Technology, which held its first general meeting about ten days ago. One of the first things to be stressed by the latter Society was the tremendous importance of vocational training for all those engaged in milk production or distribution. That the dairy farmer should, like any other competent professional man, receive some kind of qualification or charter before being allowed to practise on his own responsibility has already been suggested; it was emphasized at the opening meeting that this idea should be extended to the distributing side of the industry, so that everyone having, for example, the responsibility for running a modern pasteurization plant with its complicated machinery should have had a thorough training for his job and be certified as a competent technician. The Society of Dairy Technology has been founded to improve technical practice throughout the whole dairy industry, and to increase the sense of professional and social responsibility amongst all working in it. The beneficial results of its activities will surely accrue steadily in both the immediate future and the post-war years, and The Nutrition Society, only a couple of years its senior, and the Food Group, almost antediluvian in comparison, will join in giving this promising young newcomer their blessing.

The Production, Marketing and Supply of Milk

Mr. J. L. Davies (Milk Marketing Board, Thames Ditton, Surrey)

In preparing my paper, I have drawn extensively on the material available in the Statistics Department of the Milk Marketing Board, and I record my thanks and appreciation for the great assistance which I have received from Mr. E. D. Ashton and others of that Department. The use which I have made of the basic statistics is, of course, my own responsibility. All the tables refer to England and Wales.

The aspect of the subject which has been allotted to me in this discussion is tremendous; it covers the whole process from the dairy cow to the consumer. Much has been written on it by individuals and it has been surveyed from time to time by societies and commissions. I hope

to avoid covering the same ground which has been so well cultivated. I shall try to refer to some important problems and main trends, conscious all the time that within these lie hundreds of technical matters which are being handled daily by a host of workers, and also that to appreciate fully the broad essentials it is necessary to have detailed knowledge of recent developments in this complicated, difficult but important industry.

Production

In the first place I wish to emphasize that the milk industry, that is to say the production of milk for sale, the processing and distribution of it, is one of the biggest in this country. No exact measure of its size is possible, but its scope can be estimated roughly from information which is now available. On the dairy farming side over 150,000 farms are engaged in the production of milk for sale, and the numbers of farmers and workers employed on these for this purpose cannot be less than 300,000. The numbers engaged in transport, processing, handling and distribution are more difficult to ascertain, and the best estimate I can suggest is from 120,000 to 150,000. This gives a total of between 400,000 and 500,000 gainfully engaged in the industry which begins with the dairy cow and ends with the milk bottle on our doorstep. The numbers of workers engaged in manufacturing milk products from home milk supplies are included in the total. This has been done on the ground that, while the main purpose of the industry is to supply liquid milk, the working up of the surplus is a necessary part of the process. These figures exclude those employed in important ancillary industries engaged in supplying the dairy industry with feeding stuffs, farm, factory and dairy equipment, and supplies of all kinds.

Estimates of capital invested are most difficult but, dealing with pre-war conditions and values, and without seeking meticulous accuracy, I estimate that the total valuation of tangible assets used directly in production, transport, processing and distribution may amount to about £350,000,000 to £400,000,000. Bringing these rough figures together, one can see that in this country it requires the effort of one man and £750 to £1000 of invested capital to bring every day 10 gallons of milk from the cow to the consumer. Obviously this is not the full picture, because feeding stuffs and countless other materials are used in the various processes, but these need not concern us today.

On the production side the first, and perhaps the most important, fact is that our supply of milk is maintained by the efforts of more than 150,000 farmers, each one a separate and independent producing unit. Conditions on the individual holdings vary tremendously. We have the efficient and the inefficient producer, the small, the medium sized and the large producer, the specialist dairy farmer and the mixed farmers of all types. We are now in a position to show the distribution of the holdings selling milk, according to the size of herd, and these are set out in Table 1 in the form of a simple summary of figures recently obtained for England and Wales.

Table 1 shows the distribution for the country as a whole, but obviously there is a wide variation between individual counties and often from district to district. To illustrate this point, some figures comparing the

TABLE 1

SIZE OF HERDS FROM WHICH MILK IS SOLD

No. of cows in herd	Per cent. of total herds	Per cent. of total cows
Under 10	36	13
10 and under 25 ..	45	42
25 and under 50 ..	15	31
50 and over	4	14

distribution according to size of herd are given for two individual counties in Table 2.

TABLE 2

SIZE OF HERDS FROM WHICH MILK IS SOLD IN TWO INDIVIDUAL COUNTIES

No. of cows in herd	Berkshire		Devonshire	
	Per cent. of total herds	Per cent. of total cows	Per cent. of total herds	Per cent. of total cows
Under 10	14	3	53	31
10 and under 25 ..	37	22	43	58
25 and under 50 ..	34	43	4	10
50 and over.. ..	15	32	0	1

The statistics of the Milk Marketing Board show that the average number of cows in the dairy herds from which milk is sold is now about sixteen, but it is clear that this average value is quite inadequate to show the essential nature of the industry and its use can often be misleading.

In the past ten years very large numbers of farmers have turned to milk selling. This followed the development of the Milk Marketing Scheme which, in a period when other branches of farming were depressed, ensured a market for all supplies and a regular monthly cash payment. The number of producers selling milk in 1933 was about 100,000; today the number is 158,000. The stage is now reached where most of the farms on which herds of cows are kept sell some milk. The statistics of the Board show that of the total number of dairy cows of all types, beef cows included, kept on farms in this country, more than 85 per cent. belong to herds from which milk is sold. The remainder of the cows are kept mostly for purposes of rearing or beef production, apart from a substantial number kept on holdings for supplying milk to farm and other households. Moreover about half of all the holdings in this country which are over five acres sell milk. This is not to say that the production of milk for sale is the main business on all of them, but before the war it was estimated that the milk output represented in cash about a third of the total agricultural output.

There have been many discussions on the optimum size of herd for efficient production but, whatever the conclusions, clearly the main

boundaries are set for us, and we have to operate largely within them. This is not to say that there is no room for adjustment. On the contrary there should be considerable rearrangement of holdings, but this cannot alter the main pattern of the industry. Obviously many of the herds are too small for economical management and a full use of labour. Many of the holdings are unsuitable for one reason or another for milk production. Some of the herds may be too large for efficient management, but it will probably be agreed that there is a wide range of size of herd, from fifteen to seventy, possibly to more than a hundred, cows in which efficient production can be organized, and the range of costs of production for a similar service should be quite narrow because these are influenced primarily by factors other than size of herd. The small family farmer is not at a serious disadvantage in dairy farming if the technique and organization for production on his holding are good.

Looked at as a whole, the dairy farming industry throughout the country shows a wide variation, not only in breed and type of cow, important though these are, but also in the systems of farming and in the purposes for which the cows are kept. We have at one extreme the dairy farm which is organized entirely for milk production, with the farmer judging results by the total output of milk in relation to materials and labour used in the process. At the other we have large numbers of farms selling milk from herds kept mainly for the purpose of breeding and rearing cattle, and only milk surplus to farm requirements being sold. We cannot yet classify on this basis the total number of holdings selling milk, but it is evident that any figures of average yield of all dairy cows in this country, when these are used as an index of the efficiency of output of the industry, can be very misleading. The figure taken as the average yield of milk per cow for the country as a whole before the war was from 500 to 550 gallons, according to the season. The figure is much lower now because yields have declined in war time and large numbers of small herds, from which yields per cow are relatively low, have turned to milk selling.

The herds in which milk records were kept, numbering up to the end of 1942 about 4000 with 120,000 cows, showed average yields in pre-war years of 700 to 750 gallons. These herds are undoubtedly better than average and are not representative of the great majority of herds in the dairy farming industry. To give a fair picture of dairy farming in this country, it is necessary to give a figure for the yield per cow in the dairy herds which are kept mainly for the purposes of milk selling and from which the greater part of the liquid milk supply normally comes. These are situated mainly in the older established dairying districts, where the farmers have a long experience of producing milk and where conditions generally are suitable for dairy farming. The statistics available to the Milk Marketing Board of sales of milk from all herds and those provided by the Agricultural Economists from the sample of milk costing farms, excluding herds in some areas, indicate that the average yield of cows on farms in the main dairy farming areas in England was before the war about 600 to 650 gallons per cow, according to season. Needless to say, the averages for some herds are very much higher and for some much lower. A good deal depends upon whether herds are self sufficient, breeding their own replacements, or whether they are "flying herds"; yields in

the latter type of herd on a basis of the number of cows in the herd are naturally considerably the higher. When discussing our milk production farms in this country, I prefer to think of yields in terms of these figures, bearing in mind that they are about 100 gallons per cow higher than the general average and the same quantity below the figure for herds where records are kept.

It is important to get as accurate a picture as possible of the position before discussing the efficiency of the industry and particularly before beginning to compare the yields of our cows with those in other countries, where conditions may be quite different. This is not to say that all is well on our dairy farms; on the contrary we all know that tremendous improvements can be made in a comparatively short time, if the proper methods and organization are used, and these will both improve efficiency in production and benefit producers. Steps are already being taken which may yield important results. The need for improvement in the technique of production of milk for sale rests particularly on those holdings which have only comparatively recently, within the last ten years, become interested in selling milk. These have changed their market but often they have not adapted their system and methods on the farm to suit the new conditions. When we consider that over forty per cent. of the farmers who are now selling milk were not doing so ten years ago, we can appreciate how much is lacking in experience and technical efficiency on a large number of holdings. Many of the cows are unsuitable, much of the labour employed is not experienced in the art of managing cows for milk production and the methods used in production are often crude and inadequate.

I have had the opportunity in the last year or two of visiting all parts of this country and meeting dairy farmers, and I must say that I have found almost everywhere able men who are efficient and successful producers of milk with an enthusiastic, progressive outlook, and who are deeply interested in their industry. The impression left upon me has been that these men, particularly those of the younger generation, are at least equal in capacity and ability to those who are engaged in other industries and commerce. These, of course, are the leaders and, to secure an improved efficiency for the dairy farming industry, we must get the technical efficiency of the best producers applied increasingly by the body of milk producers.

We do, however, now have the organization needed to make the necessary improvements. The County War Agricultural Executive Committee organization is in touch with every producer and is charged with the duty of securing the maximum output of milk with the greatest measure of efficiency and economy of materials. Within the last year the Ministry of Agriculture has asked Committees everywhere to improve the efficiency of milk production on farms in all its aspects. Primarily the Committees are concerned with increasing the output of winter milk on every holding, but the provisions of the new National Milk Testing and Advisory Scheme enable them to supervise effectively the keeping quality of milk delivered from all farms. This is a piece of machinery which can become invaluable. More recently Committees have been asked by the Ministry to proceed to improve the types of dairy cattle by better breeding. This will lead to a measure of control of breeding and

will undoubtedly result, over a period, in an increasing output of milk from herds without adding to the number of cows. This work will involve careful survey of the dairy herd on each holding and of the facilities for milk production. Committees will be able to secure improvements mainly by educational work, by technical advice and, above all, by contact between the best producers on the local Committees and the rank and file of farmers in the same area. The sanctions which these Committees can apply make more effective their efforts to educate and advise producers.

The recording of the yields of individual cows, which most of the best milk producers agree is a necessity of good herd management, has been practised only by a minority of producers in this country. The responsibility for promoting this practice amongst producers generally has now been taken over by the Milk Marketing Board, and it is fully expected that rapid strides will be made. Milk recording must become a part of the technique of all dairy farmers.

These and other production problems are being tackled, but the whole process is mainly educational, designed to secure better management of the herds for improved output and efficiency in production by the rank and file of producers. The efforts of the County War Committees in milk production have a specific war time purpose, which is to maintain and increase milk supplies, but much of what they are planning now will form the foundation of a more efficient industry when peace arrives. The trend in dairy farming undoubtedly is towards specialization and a concentration on the production of milk for sale. The industry is now much larger, and the farmers, bearing in mind the experience of the past ten years, have confidence in its future. It is already far the most prominent branch of British agriculture.

Apart, however, from the improvement of management on individual holdings there are a few main problems of great importance which cannot be handled by War Committees; indeed, we can hardly hope for a solution to them in war time, but their solution should be in the forefront of farming policy after the war. Without solving these problems we shall not be able to establish a great and efficient industry. It may be said that they are matters for the Government but, in the first place surely, they should be explained, and proposals made for their solution by the industry itself. This industry is big enough and strong enough in organization to go a long way towards solving its own problems and to get the support and participation of the Government, where that is necessary. These matters are practical and urgent ones affecting thousands of producers, and every hour of delay in planning their solution will be a serious loss to all concerned.

First of these problems is that of buildings, equipment and water supply on dairy farms; electricity could also be included. It is well known that large numbers of dairy farms are very poorly equipped for production of milk for sale. Milk of marketable quality, however, is sold from thousands of farms in spite of this lack of facilities. We all know of these deficiencies and we know also the key place of milk in the diet of the people and the increasing emphasis on it for adequate nutrition. We know too that clean, safe milk is essential from a public health point of view, and it is only the sale of milk of this quality which will expand

the market for producers; yet farmers and their workers produce and deliver supplies under conditions which would not be tolerated by workers in the towns and cities of this country. Milk production, which at best is a hard task, under these conditions is most uninviting work, amounting almost to drudgery. Those who feel that I am exaggerating should try their hand at producing milk on a small farm with poor buildings and without a reasonable supply of water. The fact that milk supplies have been forthcoming in such rapidly increasing quantities from these holdings only illustrates the poor opportunities which small farmers have for making a living.

The buildings and equipment on milk selling farms vary a great deal from district to district. Conditions are worst in the areas where small farms predominate and where milk selling has developed recently. A survey of the equipment on dairy farms in one such area has just been made, and a short summary of the results is given in Table 3.

TABLE 3

RESULTS OF A SURVEY OF BUILDINGS AND EQUIPMENT ON A SAMPLE OF MILK SELLING FARMS

State of equipment	Percentage of holdings
Cowsheds	
Satisfactory	40
Moderate	38
Poor	22
Farm dairy	
Satisfactory	35
Moderate	38
Poor	27
Water	
Laid on to cowshed and/or dairy	44
Laid on to yards only	27
No water laid on	29
Cooling	
Water directly connected with cooler	28
Tank and cooler filled with water by hand	12
No water cooler system	60
Sterilizing	
Full equipment	4
Hot water used	96

The position as shown by these figures is repeated in probably more than twenty-five counties. It is disappointing not to find this problem, and suggestions for its solution, fully developed in the various plans which have been published for post-war agriculture in this country. To mention the subject only at this stage is to leave the working out of ways and means until after the war. In many areas farm buildings and farm-houses need to be completely redesigned and rebuilt, and water supplies will have to be provided on a district, possibly on a regional, basis. The tragedy is that so many villages in rural areas have been supplied with main water and electricity in recent years without reference to the requirements of farms in the district. The need for planning the

countryside to meet *all* its requirements is obvious and absolutely necessary for an efficient agricultural industry.

If we estimate that half the dairy farms in this country need extensive adjustments and repairs to buildings with some re-equipment, and that a third of the farms need rebuilding and the provision of adequate water supplies with the least possible delay, we shall not exaggerate the position. The capital expenditure involved will not be less than £100,000,000. The problems that arise from such a proposal are many, and important matters of policy are involved. It is clear, however, that with an essential service like the milk industry we must face this matter now, and without rebuilding and replanning we shall not be able to provide an efficient basis for this important industry. Dairy farmers have far too long been satisfied to produce milk under these conditions. Much is said, and frequently, about the poor quality of milk produced in unhygienic surroundings, but the amazing thing is that people are prepared to produce it at all, and those who criticize most, often fail to appreciate that the problem goes very deep and that only substantial rebuilding and replanning of our farms can provide the basis for efficient production of a satisfactory product. This is closely connected with the problem of personnel in the industry, and better farmhouses, cottages and farm buildings, properly equipped, will go a long way to increase the recruitment of the right type of farmer and farm worker into the industry. If we plan now we should get our farms in order throughout the country within ten years after the war.

The next important problem is that of the diseases of dairy cattle. It is obvious that only healthy cows can provide a satisfactory output of milk of the right quality. A poor output arising from the high incidence of disease means low efficiency and high costs of production. It must not be forgotten that there is a public health aspect to this problem of cattle disease, and it is certain that the members of this audience are very fully conscious of it. Various estimates have been made of the annual loss of milk output through diseases. The figures are very high, and all seem now agreed that the disease of our dairy herds is a most serious deterrent to attainment of efficiency. More than this, it destroys the pleasure of herd management. Some steps are being taken already towards the solution of this problem, but they are clearly not sufficient. Looking to the future we cannot afford to let it continue, and resources used in eradication and control now and in the next few years will become a profitable national asset. Here is scope for another plan with a ten year limit.

The third major problem which is equally difficult, and which will have to be solved without delay when peace arrives, is that of the supply of labour on dairy farms. This also is a matter touching the foundations of the industry for, if the labour position is not satisfactory, the industry will decline. In dairy farming the difficulty with labour, keenly felt in war time, arises largely from the fact that cows need attention on seven days of the week, and cowmen and their assistants, and farmers and their families on small farms, are under normal conditions about the only section of the community who, because of the nature of their work, have to do a seven days' duty every week. This generally means a long working week, and because the units of production are mostly small and the work

highly skilled, almost a personal matter, it is difficult on the majority of farms to utilize the device of the "spare" man or the rota system and, in any case, the labour is not available for this in time of war.

This problem must, however, be faced when peace arrives and, by an addition to the total labour strength, a six day working week must be arranged on the larger dairy farms. On the smaller family farms the problem is more difficult, but even there the economic conditions in the industry should be such that on these holdings more labour could be hired where necessary. It is difficult to understand why the conditions of work for those engaged in the production of this vital commodity are more onerous and financially less attractive than for those who carry, process and distribute the milk after it leaves the farm. As a general rule these latter workers have a six day week, and even now probably earn more than those who do the skilled work of the production of milk. The margins of difference in wages before the war were considerable. In the past this problem did not attract much notice because conditions in most branches of agriculture were depressed, and dairy farming did offer a living, although an arduous one. The position now is very different and milk producers realize that their lot is harder than in other branches of farming, and is not compensated by better returns. There will not be ten years in which to plan a change, the matter will become urgent as soon as the war is over.

These three main problems on the production side of the industry have been treated at some length because of their fundamental importance, and because each of them involves important decisions of national policy. The producing end of the industry must be fitted to meet the milk requirements of a modern society, and the only sure basis for the future is to seek to make the foundations of an efficient industry without delay. The three main problems which have been mentioned need a solution boldly conceived, and this should be well within the capacity of our resources immediately after the war. If these matters are put right all the other technical improvements will be facilitated, and the industry will be in a position to take the strain of a full nutrition policy.

Marketing and Distribution

The many problems of selling a primary product in a fairly free and uncontrolled market tend to disappear when the Government guarantees prices to producers and the product is in short supply. It is not necessary to recount today the experience of milk marketing before the war because conditions now are so very different. The progress in milk marketing up to the war had brought an assured, expanding market to milk producers, but the responsibility for the level of supplies and the prices received was taken largely by the producers themselves, through their own organization. Most of us who have followed the subject closely believe, however, that we must develop from the old position. It is probably a truism to say that marketing organization cannot stand still, and especially is this the case after passing through a period of world upheaval such as we are now experiencing.

With an essential food product like milk, which is used almost universally, and which is perhaps the keystone of the national nutrition policy, it is fair to argue that in the production and handling of it there should

be an increasing element of public service. It is to be hoped that this will not mean farming or distributing milk "from Whitehall." We shall not, however, find it easy to devise an organization, quite apart from its acceptance by the parties, combining a strong element of public service with full scope for enterprise and initiative, both equally important; until the elements in such a combination are found, it is not possible to give much meaning to the now popular phrase of "public control in industry after the war." I will only venture to say that such a milk control organization should have the minimum of Government interference, but the maximum of support from the Government for providing a rapidly increasing supply of milk, economically produced and delivered in safe condition and without waste, at prices which not only give fair reward to enterprise, and wages to the workers in accordance with the skill which they employ and the exertion which they make, but which also measure fairly the service rendered to the consumer.

Producers of milk have been assisted considerably by the operation of the Milk Marketing Scheme since 1933. The industry has grown and producers have a great measure of confidence in it. With prospects of further expansion in the market for milk after the war the task of finding the market should not be difficult, but this is only a small part of the problem. The producers have undoubtedly provided a basis for the milk organization of the future. It can handle the produce of a much bigger industry, indeed it can help considerably to make the industry bigger and better, but wider decisions on national food and milk policy will have their influence in determining the form of the organizations for marketing milk after the war.

I cannot leave this section of my paper without referring to the subject of pasteurization and the quality of milk, in which I feel sure this audience is very much interested. To be quite frank, the impression I have is that far too much valuable time has been taken up by the controversy over pasteurization, which has been engaging attention for some years now, and that both sides tend to exaggerate the case which they state. It seems to be agreed substantially that milk should be pasteurized when it is distributed in large towns from supplies which have been bulked from a number of individual farms. Under modern conditions milk cannot be distributed within a few hours of its production on the farm, and effective pasteurization is necessary in the interests of producers, distributors and consumers. My personal feeling is that the greatest danger to the public at present arises in those dairies which bulk supplies from individual producers, but which fail to handle and pasteurize the milk efficiently before distribution.

Producers who are also retailers distribute about 20 per cent. of the total supplies in this country, and they operate mainly in rural districts, the smaller towns and the suburbs of the large towns and cities. It is not practicable to pasteurize these supplies at present and, in regard to a large part of them, I feel we should lose something by doing so. I happen to prefer raw milk if I can get it, but agree entirely that this should be produced from healthy cows, by approved clean methods. To insist on pasteurizing these supplies would be wasteful and costly and, in the long run, it would surely cost the nation more to pursue this course than to clean up the herds and to free them from disease. This step is

so necessary from another point of view as well, that it is very essential for rapid strides to be taken in this direction.

I have been hoping for a plan to be made and introduced by the Government so that in 10 years' time only milk which is either properly pasteurized or designated "tuberculin tested" will be distributed to consumers. This would be to the interest of producers as well as consumers, since it is only on the basis of increased confidence given to the public and to those who are responsible for the nutrition and health of the people that we can plan the great expansion of the industry which is necessary. Do let us make it 10 years, but do let us have a plan to deal with this matter of quality; otherwise the far greater problem of the quantities required for the nutrition of the people will still have to take second place.

Supplies

It is now well known that the dairy farmers of this country have been able to maintain, even to increase, the supply of milk during the war. The Minister of Agriculture stated recently that the total quantity of milk made available last year was the greatest ever attained. This has been done in the face of great difficulties, particularly the shortage of suitable farm labour and a substantial reduction in supplies of imported feeding stuffs. Dairy farmers are now planning to increase milk supplies in the winter months still further, and those will be produced more and more from feeding stuffs grown on the extended arable acreage on dairy farms. The milk position in this war is infinitely better than it was in the last, and it will be agreed by the authorities that the generous supplies which have been available up to now have been a potent influence in maintaining the health of the people under the stress of war conditions.

The Ministry of Food has realized fully the value of milk in the diet in war time and, thanks to the special arrangements made, the heaviest consumption has been in those sections of the community which need it most. The Ministry of Agriculture, the War Agricultural Executive Committees and, most of all, the dairy farmers have ensured the supplies necessary to meet the requirements of our war time food policy. While we can say that the position to date has been satisfactory, we cannot lapse into complacency for an instant, because the difficulties of production of milk in war time are very real and only the greatest measure of continued support, encouragement and assistance can ensure a maintenance of supplies.

The course of milk supplies and consumption of milk in the past ten years is illustrated in Table 4.

TABLE 4

MILK SOLD OFF FARMS*

Year	Total, million gallons	Index
1933–34	855	100
1935–37 (mean for 2 years) ..	1007	118
1937–39 (mean for 2 years) ..	1091	129
1942–43	1110	130

* Sales through the Milk Marketing Board.

Before the war a large proportion of the supplies, particularly in the summer months, was manufactured into dairy products and an important manufacturing industry has developed in this country for handling these. Since then, the demand for liquid milk has increased enormously and, although supplies are running at a very high level, it has not been possible to provide all that the public requires in the winter months. The quantities of liquid milk that consumers will take under present conditions, when given freedom to buy up to their full requirements, have exceeded all expectations. The position is shown in Table 5.

TABLE 5

USE OF MILK SUPPLIES FOR SALE AS LIQUID MILK AND FOR MANUFACTURING PURPOSES

Year	Percentage of milk supplies manufactured	Total sales of liquid milk, million gallons	Index of total sales of liquid milk
1933–34	25	643	100
1935–37 (mean for 2 years) ..	33	673	105
1937–39 (mean for 2 years) ..	30	760	118
1942–43	10	1000	155

The total of sales of liquid milk for 1942—43 must be interpreted with due regard to the measure of restriction in deliveries in the winter months when total supplies fell short of requirements. A better indication of current demand for liquid milk is given by a study of the statistics for the month of May of this year, when the degree of restriction was only nominal. In that month the quantity of milk sold for liquid consumption reached a total of nearly 96 million gallons compared with 66 million gallons in the same month of 1939. This is an increase of 45 per cent. in a comparatively short period and, at this rate, the consumption for the year would be 1150 million gallons.

Needless to say there are numerous problems, many of them acute, involved in the handling of such large quantities of liquid milk in war time. They arise on the farms, in the transport organization, in processing and in distribution, and it would be wrong to give the impression that this colossal quantity of liquid milk is being handled daily without a real effort on the part of all concerned.

When the statistics of the Milk Marketing Board are used for calculations of the consumption of milk in this country, an allowance must be made to cover supplies not recorded by the Board. These are supplies used mainly in farm households, by farm workers and by some other rural families. Estimates to include them have been made and, in Table 6, are set out the results of a calculation to show the consumption of liquid milk per head of the population pre-war and subsequently.

A great deal of light was thrown before the war on the subject of consumption of liquid milk by Sir John Orr (1936) and others interested in nutrition. Studies by Dr. Keith Murray (1937) emphasized the variation in consumption between different income groups and between individual families within these groups. Most were agreed that the

TABLE 6

ESTIMATED CONSUMPTION OF LIQUID MILK PER HEAD OF POPULATION

Year	Pints per head per day	Index
1933–34	0·37	100
1935–37 (mean for 2 years) ..	0·38	103
1937–39 (mean for 2 years) ..	0·43	116
1942–43	0·57	154
May, 1943	0·65	176

chief factor, though not the only one, determining the level of consumption in individual households was the income per person available for spending on food. To improve nutrition and to expand the market, steps had been taken by the Ministry of Agriculture and the Milk Marketing Board before the war to develop the use of milk in schools, and by mothers and young children in the home. The prices charged in these schemes were low and a state subsidy was provided. It is since the war, however, and as part of Ministry of Food policy that the great expansion under the now familiar National Milk Scheme has taken place. The Treasury has been generous in its subsidy and it is understood that under the National Milk Scheme more than 80 per cent. of the nursing and expectant mothers and young children under five receive their daily pint of milk, either free or at a much reduced price. Undoubtedly this is an excellent scheme which we cannot as a nation afford to drop or even curtail when peace arrives. There has also been a considerable expansion in the provision of milk to the schoolchildren since the war and a far greater number of these are now drinking two-thirds of a pint of milk daily instead of one-third, as previously. These two schemes now account for about 15 per cent. of the total consumption of liquid milk, and they are an important contribution to a nutrition policy.

It is often wrongly assumed that these schemes have been wholly responsible for the increase in milk consumption during the war. The facts show that recently the increased distribution under these schemes to the priority classes accounted for rather more than half the total increase in consumption compared with the pre-war level. The figures for consumption in May this year compared with those for the same month in 1939 show that the proportion of the increase directly due to these schemes is rather less than 40 per cent. The remainder of the very substantial increase is caused no doubt partly by the shortage of other foods in war time and partly by the great improvement in the purchasing power of the wage earners in this country. If a survey were made now to ascertain the level of consumption at different income levels the results would be very different from those which were found before the war. Those families with the largest number of children and a relatively small income per head might well show the highest consumption per head.

Out of this short statement of the facts as they appear now, arise a number of important questions, each probing into the future. What rate of liquid milk consumption should be arranged for the people of this country in the next five or ten years to satisfy the requirements of an

enlightened and progressive nutrition policy? Will the people purchase the great proportion of this supply at market prices in the face of the competition of other foods, and, if not, will the Government be prepared to continue, and even to extend, its present policy of food subsidies to ensure adequate consumption of milk? Will supplies of milk be made available by the dairy farmers of this country to meet these requirements?

The nutrition experts seem to be agreed that a high consumption of liquid milk is essential for an adequate diet. About the precise quantity there may be difference of opinion, but an average consumption of three-quarters of a pint per head daily with proper provision within this average figure for heavier consumption by the "priority classes" seems to be indicated. With this figure as a basis, the total consumption of liquid milk in England and Wales would be about 1430 million gallons, representing a minimum output from farms of not less than 1600 to 1700 million gallons. This calculation is made on the basis of a considerably reduced degree of seasonal variation in production as compared with the pre-war years. However, this total quantity involves an increase of at least 500 million gallons on the output of 1942—43, equal to 40 to 50 per cent., which is the product of over a million additional dairy cows at the present level of yields.

This is the size of the task. I am confident that, given fair warning and a clear policy, the dairy farming industry could make the supplies available within ten years after the war. A good part, probably more than half, of the increase should come from improved yields of existing dairy herds, the remainder from an addition to herds and an extension of dairy farming.

A development of this kind will mean, of course, much greater emphasis on dairy farming in the agricultural industry of this country. This, many of us feel, is inevitable and desirable. The product is perishable, it has to be marketed without delay, and thus does not face direct competition from overseas. In addition to this, our climate and soil conditions, the size and organization of our farms, and the tradition and experience of our farmers and farm workers in livestock management give us advantages in production which we should exploit to the full. The extension, equipment and improvement in efficiency of our dairy farming industry will enable our farmers and farm workers to make their best contribution to world food policy.

In view of this position it becomes imperative to tackle boldly the three main deficiencies on the production side which I mentioned earlier. On the consumption side, we must assume that the School Milk and National Milk Schemes will be continued on the present basis after the war, and there must be an extension in other directions of the policy behind these schemes. The introduction of a system of children's allowances as part of the Beveridge plan can make a substantial difference to the demand for milk. A policy of full employment is most necessary for a high level of consumption. These are matters of vital interest, because these great national factors determine to a large extent the size of the milk market. National food and milk policy must be decided first, and when this is done our agriculture, and in particular our dairy farming industry, can begin to take shape. An increase in consumption and the necessary adjustments in dairy farming to meet the demand

should go hand in hand on a definite planned programme. These views are best expressed in a passage in the resolutions of the Conference at Hot Springs (United Nations, 1943), with which I will close this paper: "The first steps toward freedom from want of food must not await the final solution of all other problems. Each advance made in one field will strengthen and quicken advance in all others. Work already begun must be continued. Once the war has been won decisive steps can be taken. We must make ready now".

Summary

(1) The production and handling of milk is one of our biggest industries.

(2) We need a ten year plan now for:

(*a*) Rebuilding and equipping our dairy farms and providing water supplies and electricity.

(*b*) Making the dairy herds free of disease.

(3) Labour in dairy farming should have a six day week. This matter is urgent.

(4) The form of organization of marketing and control for the milk service after the war will depend largely on national food policy.

(5) Consumption of milk in this country should be raised over a period of ten years to meet the nutritional standards.

(6) The dairy farming industry could provide the greatly increased supplies required over the same period.

REFERENCES

Murray, K. A. H. (1937). *Milk Consumption.* Oxford: Agric. Econ. Res. Inst.

Orr, J. B. (1936). *Food, Health and Income.* London: Macmillan.

United Nations Conference on Food and Agriculture (1943). *Final Act of the United Nations Conference on Food and Agriculture.* [Cmd. 6451]. London: H.M.S.O.

Discussion

Dr. W. R. Wooldridge (National Veterinary Medical Association of Great Britain and Ireland, 36 Gordon Square, London, W.C.1), joint opener: There are numerous factors affecting the quality and quantity of milk.

(*a*) *Factors Affecting Quality.* Many of these apply to individual cows and are not important when the milk is bulked. The factors which are of importance are: (1) *The ancestry of the animals.* Mr. Davies has already stated that the average milk yield is 500 gallons per annum; a cow in a true dairy herd produces 600 to 650 gallons, and in the better dairy herds, 750 gallons; a high proportion of cows produces, however, only 200 to 300 gallons. Such low yields can be overcome in a very large measure by an intelligent breeding policy coupled with milk recording. (2) *Feeding.* (3) *Cleanliness*, which includes bacterial cleanliness. Inadequate cow-sheds lead to heavy bacterial contamination of milk, decrease its keeping quality and increase wastage. Clean milk cannot be produced in filthy surroundings and improvement of farm buildings and of farm water supply is essential. (4) *Disease.* Though perhaps too much has been made of the contamination of milk by the bovine strain of the tubercle bacillus and of its effect on man, it is not sufficiently realized that several

other diseases, some of bovine and some of human origin, are transmitted by milk.

(*b*) *Factors Affecting Quantity.* The three main diseases affecting quantity are mastitis, contagious abortion and temporary infertility; the losses due to these causes are shown in Table 1.

TABLE 1

EFFECT OF DISEASE ON NATIONAL YIELD OF MILK

Disease	Incidence per cent.	Loss of milk yield	
		Individual, per cent.	Total national, million gallons
Mastitis	25	12	48
Contagious abortion: actual abortions ..	10	25	40
Temporary infertility	30	23	110

These diseases are responsible also for indirect losses by leading to the need for early replacement of the dairy cow and by causing through the death of female cows a delay in the replacement of the milking stock. The further loss in milk production occasioned by wasting diseases such as tuberculosis, Johne's disease and parasitic gastro-enteritis, and by bad feeding should not be forgotten. Table 2 shows that the present extent of schemes to control disease among dairy stock is very small in proportion to the total number of dairy cattle.

TABLE 2

PRESENT STATE OF CONTROL OF DISEASE IN DAIRY CATTLE

Type of control	Number of herds	Number of cattle
Tuberculosis: establishment of attested (T.B. free) herds	16,000	500,000
Contagious abortion, mastitis, Johne's disease, sterility: voluntary control scheme	6163	254,885
Contagious abortion: vaccination outside voluntary scheme	6000	200,000
Little or no control	*c.* 120,000	*c.* 2,500,000

Professor A. W. Ashby (Department of Agricultural Economics, Agricultural Research Building, Penglais, Aberystwyth), joint opener: There are one or two inferences that can be drawn from Mr. Davies' figures. According to him it takes from £750 to £1000 of capital and the labour of one man to bring 10 gallons of milk from the farm to the doorstep each day. If that estimate is correct, it takes one man a whole year with £750 to £1000 of capital to handle 3650 gallons of milk. With no allowance for railway transport and other charges, the direct labour charge is 1s. 4d. per gallon. That is to say, 1s. 4d. per gallon for a commodity that is mostly water. It is not possible to get order into the industry until we are able and willing to take drastic steps. If we take the question of the size of the holding, the size of the herd, the quality of the buildings

and the water supplies with which milk is produced, that is to say, if we are thinking of the fundamental conditions of land ownership, then I would say that the remedy is simple. If there is no real prospect of getting £100,000,000 spent, and spent economically, within 10 years after the war then the nation should put its capital into its own estate. National planning and supplies of building materials, aided by cheap national loans, are essential. In 1938 there was a considerable number of people who had contracts with the Milk Marketing Board, and were at the same time obtaining public assistance because the holdings did not produce enough to maintain them over the year. There are great contrasts in the dairy industry. On the one hand you may have a man handling only 8 cows and on the other a man handling 25 to 30 cows and, on the whole, doing the better job.

Certain economies can be made by the eradication of disease. It has been stated that diseases add 25 per cent. to the cost of a gallon of milk. I consider that these figures are erroneous and that the cost can be reduced by this means by not more than 5 to 10 per cent. The voluntary scheme mentioned by Dr. Wooldridge has many advantages, but the support it is receiving from the farmers does not indicate that the losses in dairy herds are as substantial as some people consider. It is doubtful if the total casualties amongst the herds amount to more than 2 per cent. The total casualty rate in the years before the war, including deaths and screws, that is animals sold for less than £6, was less than 4 per cent. The average period between calvings in this country is 13 months; with the best management it may be reduced to 12 months, thereby saving one-twelfth of the time.

Mr. Davies has told us that we should need a 40 per cent. increase in milk production after the war to meet the estimated nutritional needs of the population, and he has wisely said that he thinks we could get half of that amount by increasing the milk yield and half by increasing the number of cows. The yield could be increased by 10 to 15 per cent. in 2 years by improved feeding and management and by reduction of disease but, to secure a further increase, attention must be turned to breeding, and that is necessarily a slow process. It is only rarely and for short periods that it has been possible to raise the average yield of a country by more than 2 per cent. annually. It would be quite easy to achieve an annual increase of about 2 per cent. for 10 years or so. After that we should be dependent on selecting and breeding cows with the capacity for converting foodstuffs into milk more economically. It might be possible to do that by changing over to the true milking strains, but at the moment I personally am afraid that the change over from Shorthorns to Friesians on many farms would be a change from first to second rate cows. The cow producing 300 gallons is about $2\frac{1}{2}$ times as efficient as the store and beef bullock in turning cattle feed into food which human beings can assimilate.

Dr. A. W. Stableforth (Veterinary Laboratory, Ministry of Agriculture, Weybridge, Surrey): Professor Ashby has expressed the view that the effects of disease on the national milk yield cannot be as large as has been stated, or farmers would have done more about them. This assumption is seriously open to question. Numerous instances could be quoted of

serious losses from disease which have just been accepted as inevitable. Many years' work on mastitis and abortion leads me to support the essential validity of the figures quoted by Dr. Wooldridge. The figure for sterility can be criticized on the grounds that it is too much to expect a calf every 10 months, but the loss is undoubtedly large. Professor Ashby said also that disease control measures would not produce more than 5 to 10 per cent. improvement in the annual yield; even this percentage would well repay the cost.

Apart from need of capital, Mr. Davies listed 3 main points in his 10 years' plan: better buildings, equipment and water supplies, control of disease, and an adequate supply of trained labour. Improved feeding and breeding are also of first importance, particularly on the smaller farms. All these points necessitate improved education of everybody on the farm, and close co-operation among those outside who can help to bring home the knowledge already waiting to be used.

Lt.Col. G. B. C. Rees-Mogg (Clifford Manor, Stratford-on-Avon): Ponds in which cows congregate in summer and into which they may discharge micro-organisms responsible for Johne's disease and contagious abortion are a very likely source of infection. Mastitis and tuberculosis may be carried also by flies from the teats of one cow to those of another.

I do not agree with Professor Ashby that screws disposed of yearly amount only to 2 per cent. of the herds. If a farmer has disease among his cows he naturally does not talk about it but gets rid of the sick cows as quickly as possible. In my opinion wastage might in some years be as high as 20 per cent.

The increase in consumption of liquid milk mentioned by Mr. Davies is largely due, I think, to the distribution of free and cheap milk and to the disappearance of tinned milk which was very popular in large towns before the war.

Professor J. R. Marrack (London Hospital, Whitechapel, London, E.1): It has been suggested by Mr. Davies that the milk supplied by producer retailers should not be pasteurized. This milk is as liable as any other to contain pathogenic bacteria and to be produced under unsatisfactory conditions. The matter of pasteurization is urgent because, under the present scheme of milk distribution, the stimulus of competition is removed, milk may be sent considerable distances to make up deficiencies in a retailer's supply, and shortage of labour makes the production of wholesome milk more difficult. We should study the methods used in other countries. I am told that in Austria there are pasteurizing plants in the villages to which milk is brought straight from the farms.

Mr. J. L. Davies replied: In my paper I tried to outline the structure of the milk industry and to indicate in very broad terms a few of the bigger problems of the future. The members who have taken part in the discussion have not disputed the essential points, but they have added to them a number of interesting details. I believe there is no serious disagreement on what remains to be done in this industry, the aims and objects are fairly clear, it is on ways and means that difficulties arise, and some disagreements too.

I agree with the valuable points made by *Dr. Wooldridge*, except that I can never bring myself to accept his statistics showing the national loss of milk supplies through the incidence of dairy cattle diseases. On the whole I feel that the figures are placed unduly high but, even if the actual loss is half this estimate, the problem of diseases in cattle is of growing importance to the nation and to milk producers, for this and for other reasons mentioned by Dr. Wooldridge. Undoubtedly the resources we are using in controlling and eradicating diseases in dairy cattle are far too small, and out of all proportion to the size and importance of the problem.

Professor Ashby has rightly emphasized the importance of the output of milk per person employed in the industry. My estimates need considerable refinement before output can be assumed in these terms with confidence, but even a rough calculation shows that this is the main economic problem on the production side of the industry. I feel intensely the need for re-equipment of dairy farms. Professor Ashby has carried this question further into the controversial ground of ways and means. I have a great deal of sympathy with his point of view. I am sure it is wrong for farmers and their workers to be asked to produce milk, a vital food, with poor and inadequate equipment, quite apart from the serious loss in efficiency which arises directly from this. I fully agree with Professor Ashby that if we are to provide an adequate supply of milk for the people we must concentrate on improved breeding of dairy cattle. I feel that the improvement in yield which has been shown in the past twenty years is no indication of what can be achieved if the scientists and farmers concentrate on this aspect in the next ten years.

Dr. Stableforth's argument was mostly with Professor Ashby and I am happy to leave the experts to decide what is the actual loss in milk from diseased cattle, as long as this does not take our attention away from the work of cleaning up the herds.

I am in general agreement with the remarks of *Col. Rees-Mogg* and *Professor Marrack*, but I still hope that no attempt will be made in this country to pasteurize milk delivered by producer retailers in rural communities. The cost of any such scheme would be very much greater than that of cleaning up the herds on the farms involved. Personally, I cannot regard pasteurization except as a necessary evil.

Bacteriological Aspects of Milk Processing and Distribution

Dr. A. T. R. Mattick (National Institute for Research in Dairying, University of Reading)

The Committees of the two Societies have shown their wisdom in preserving a certain elasticity of title, but they could have saved the audience the tedium of listening to me by recommending it to read "The Pasteurization of Milk" by Professor G. S. Wilson (1942), a most admirable, reasoned and judiciously cathartic summary of certain of the facts for those biassed, uninstructed and vociferous opponents who have recently been misinforming the public by letters to the press.

I welcome this opportunity of reiterating in public my conviction registered in a resolution at a meeting of the Division for the Social and International Relations of Science of the British Association in Reading in March, 1939, that in all communities with a population of 20,000 or more, pasteurization, properly supervised and controlled by competent personnel, should be obligatory. I hope I may say that in the past I have not been unmindful of the interests of all aspects of the milk industry but, as a bacteriologist, I hold that *proper* pasteurization will not only virtually abolish milk borne disease but, for several reasons, will encourage the consumption of milk which even now is far lower than the optimum for nutrition.

This paper is not, however, concerned with the politics, but with the bacteriological aspects, of the problem. I would say at once that, however desirable pasteurization may be for milk and its by-products intended for consumption, in one form or another, by human beings, it is at least as desirable for stock feeding. It has also to be recognized that for bacteriological and other reasons, such as the destruction or inactivation of enzymes, pasteurization is of great value and importance in dairy manufacture.

I should define the process of pasteurization as one of raising the milk to some temperature well below boiling point for a time which varies inversely with this temperature; if it is grasped at once that the death of micro-organisms in all conditions where heat is applied is, above a certain minimum, a function of time and temperature, and that the influence of these two factors is inseparable, the infinite flexibility of the process with modern plant will be easily understood.

Objects of Pasteurization

From the public health aspect milk is pasteurized to kill the common pathogenic organisms of many kinds which may occur in raw milk. It is perhaps ultimately of little less importance that proper pasteurization of good raw milk so enhances the keeping properties that the consumer is able to make full and unrestricted use of milk in its most acceptable form. If, as I hope to show, milk has not a sufficiently long keeping quality, it is not the fault of the process but of deficiencies in its application, or in the mode of distribution of the product, or in the raw product itself.

Pathogenic Organisms

Interest naturally centres round the pathogenic organisms likely to be present in milk, particularly those of which small numbers may set up serious infection in man, such as the tubercle bacillus and perhaps *Brucella abortus*, and those which can grow freely at ordinary temperatures such as salmonellas and the organisms of typhoid and dysentery. The practice of bulking raw milk for consumption in towns, therefore, imposes a heavy duty on the distributor. Thus, it has been shown (Pullinger, 1934) that virtually 100 per cent. of bulks of 3000 gallons of milk in tankers contain living tubercle bacilli, sometimes in considerable numbers and always enough to set up infection in the guineapig by the usual method; further, my own experience (Mattick and Hiscox, 1939) with smaller bulks shows that danger is not confined to large volumes.

The Tubercle Bacillus, because in milk it has a resistance to heat rather greater than that of the other more common pathogenic organisms, which

in the main may be said to be destroyed at about 140° F. in 10 minutes, has been adopted as the organism of reference. The requirements for officially sanctioned holder pasteurization are heating at not less than 145° and not more than 150° F. for not less than 30 minutes followed by adequate cooling.

The classic work of North, Park, Moore, Rosenau, Armstrong, Wadsworth and Phelps (1925) with pasteurizing plants showed that human and bovine tubercle bacilli in raw milk are killed by exposure to a temperature of 138° F. for 30 minutes. It thus appears that our official regulations embody a large margin of safety. The results of more recent laboratory experiments in this country have been rather equivocal (White, 1926; Meanwell, 1927), as have certain experiments on animals carried out by Zeller, Wedemann, Lange and Gildemeister (1928) in Germany. These experiments suggested that, on occasion, tubercle bacilli in milk might survive pasteurization at temperatures above those laid down by North and Park. It is clearly of the greatest importance that those who carry out work of this character should use more than the usual care in the design and technique of their experiments and in the care and management of any experimental animals. Nevertheless, it may be well not to dismiss all inconvenient findings, and to face what I believe to be no more than the possibility that, when *abnormal* milk is heated, local coagulation due to the acidity of the milk, or the presence of flocculi of other types, may sometimes allow the tubercle bacillus to escape destruction. It is, however, unlikely that under good practical conditions of pasteurization any significant number of organisms escapes destruction. My reasons for this statement are two: (1) In holder pasteurization the actual time of exposure to a temperature of 140° F. or above always exceeds 30 minutes because, for the bulk of the milk, the emptying time and the time of raising the temperature to 145° F. are additional; (2) An apparatus for filtration is included in the plant, which automatically removes particles of a size and nature likely to protect organisms from heat at the temperatures used. Filtration is of course important for other reasons and has not received the attention it deserves. It may be repeated that it was with pasteurizing plants that the work of North and Park was carried out and that examinations of vast numbers of commercially pasteurized samples have given negative results. The proof of the pudding is in the eating!

In considering the important matter of the freedom of milk from living tubercle bacilli as well as for other reasons which I shall discuss later, the quality of the raw product is of the greatest importance. In one matter at least, a war time measure, the establishment of the National Milk Testing and Advisory Scheme of the Ministry of Agriculture, is likely to have far reaching effects if its general application is not stifled for sectional reasons. The scheme foreshadows payment of the producer on quality, estimated by an acceptable technique, and I do not expect to see the full benefits until this plan is implemented. Before leaving the question of the tubercle bacillus it ought to be said that, before adverse reports from the field are accepted, it should be ascertained that the conditions of pasteurization were observed and that the plant was of the proper type in which, for example, it was impossible for the raw milk to reach the pasteurized milk.

Holder pasteurization is, I believe, in course of being superseded by the high temperature short time process. The new Milk (Special Designations) Regulations, 1936—41, of the Ministry of Health permit provisionally the heating of milk at a temperature of not less than 162° F. for not less than 15 seconds. Theoretically, exposure to a temperature of about 162° F. for 15 seconds should have the same lethal effect on organisms as exposure to one of 144° F. for 25 minutes, but this process is one of continuous flow in which the time of heating to the holding temperature is perhaps even more important than in holder pasteurization. The time of exposure to a temperature above 140° F. is a considerable proportion of the total time in the range lethal for pathogenic organisms. It is, therefore, necessary to take into account the duration of the heating process. The fact that the process is one of continuous flow makes laboratory experiments, faithfully reproducing practical conditions, very difficult, and I have not as yet seen any published work which is beyond criticism in this respect. The practical evidence for the destruction of tubercle bacilli is I think convincing but not yet extensive. A considerable body of American work points to the conclusion that exposure to 160° F. for 15 to 16 seconds is satisfactory, and some recent experiments of a colleague and myself (Mattick and Hiscox, 1939) indicate that the requirements of the Provisional Regulations as to temperature and time allow a margin of safety. This new process is very attractive for many reasons but it will have to be carefully controlled. We have recently found in work with the National Physical Laboratory, that the thermometric apparatus, translated from holder plants, may lack that speed of response to changes in temperature which I believe to be essential in some continuous flow processes (Hall, 1944). We have found that thermo-couples are admirable for the purpose and I hope to see them universally adopted.

For ensuring the destruction of pathogenic organisms and for avoiding later contamination, the process of pasteurization in bottle has much to recommend it, but my personal knowledge is insufficient to discuss it from the practical and economic viewpoints.

The importance of protecting farm stock from infection has been referred to earlier. Calves and pigs are notoriously susceptible to infection by bovine tubercle bacilli in milk, whey, skim milk and other by-products. A cheap and effective process of pasteurization suitable for treating by-products before dispatch to the farm was tested by us 3 or 4 years ago (Mattick and Hoy, 1939). It embodies a controlled method of injecting steam into the product and was found to be effective at a temperature of 175° F. applied for 3 seconds. It was also found that bovine tubercle added in very large numbers were completely destroyed. The dilution resulting from steam injection is of no account in stock feeding and I should welcome a complete official ban on the distribution to animals of infected milk or milk products from creameries and factories.

Brucella abortus. My own experience, like that of others, shows that this organism is more frequently present in bulk milk than is generally realized, and I need not refer to the literature on the occurrence of cases of undulant fever in man. I am convinced that they are far more frequent than the figures show owing to failure to recognize the condition and to

make proper confirmatory diagnosis by bacteriological methods. All that need be said is that the organism has not great heat resistance and that there is no evidence of its recovery from properly pasteurized milk.

Streptococci Pathogenic for Man. Similarly, it need only be stated that the strains known to infect man are easily destroyed by heat and, as far as I am aware, have never been shown to survive correct pasteurization.

Staphylococci. These organisms are far more common in raw milk than has been appreciated in the past. They occur in the udders of very many milking cows (Shattock, 1941). They are more heat resistant than most other pathogenic organisms but have little or no power to convey infection by the mouth. In examining a large number of samples from commercial plants working at about 145° F. for 30 minutes, I have not yet encountered these organisms in pasteurized milk not contaminated with raw milk although they certainly may survive exposure at 140° F. for 30 minutes. Their importance in uncontaminated pasteurized milk does not seem to me to be great. Some strains, however, if allowed unrestricted growth in milk, produce enterotoxins which have unfortunate, though usually temporary, effects on the individual.

Other Micro-organisms. The situation regarding the common pathogenic organisms infective by the mouth may be summarized by saying that the evidence from the academic and practical aspects leaves no reasonable doubt that, after being heated at 145° F. for 30 minutes, bulk milk may be consumed without danger of infection.

It will, however, be obvious that all the necessary steps must be taken to prevent the occurrence of contamination subsequent to pasteurization.

The evidence so far adduced refers only to the milk as it leaves the efficient plant and, to complete the account, it is necessary to consider that part of the flora of the raw milk which is usually held to be non-pathogenic, and to review the possible sequelae of pasteurization in respect of organisms of this type.

It was once widely held, and the belief still has its adherents, that "within reason" not defined, milk of any hygienic quality was suitable for pasteurization. Fortunately the belief is disappearing for, as I hope to show, it is quite untenable.

In considering the bacteriology of pasteurization it is therefore necessary to begin with the raw milk. The flora of the healthy udder is numerically small and qualitatively simple, and it appears that if the total plate count of the fresh milk exceeds 2000 per ml., in most cases 300 per ml., there is an infection of the udder (Davis and McClemont, 1939). Gibson and Abdel-Malek (1940) showed in a careful examination of a small number of aseptically drawn samples from healthy animals that the only organisms present were micrococci and *Corynebacterium* sp., and Shattock (1942) also has found in examining a very large number of samples for other purposes that these organisms either separately or together are almost invariably the only flora. Gibson and Abdel-Malek found also that these organisms did not survive in milk heated to 145° F. for 30 minutes and their evidence questions a body of American opinion that the micrococci of commercially pasteurized milk are directly derived, at least in part, from the udder of the cow. Davis, Twigg and Wright (1941) have observed that if ordinary fresh milk is pasteurized in the

laboratory at 145° F. for 30 minutes and held at 34° F. it will keep without significant change for about 30 days.

The fact is that milk from healthy cows without adventitious contamination is almost completely sterilized by pasteurization. But, unfortunately, not all udders are healthy, and streptococci, mainly *Streptococcus agalactiae*, *Str. uberis* and *Str. dysgalactiae* with other streptococci less certainly pathogenic for either man or animals, together with staphylococci, are added to the micrococci and *Corynebacterium* of the healthy udder. Moreover in the course of milking, however careful, under practical conditions, other organisms gain access to the milk in varying numbers. Thus in certified raw milks, Gibson and Abdel-Malek (1940) found that streptococci and micrococci predominated. *Corynebacteria* were frequent and variable in numbers and other organisms occurred only to a small extent. After pasteurization the streptococci disappeared showing that those present in the raw milk were mainly of pathogenic types which are acknowledged to be destroyed in milk by pasteurization. The preponderating survivors were *Corynebacteria* but of a type different from those of the udder, which are not heat resistant. They grew poorly or not at all at a temperature above 86° F., were resistant to heat; they were described by Orla-Jensen (1919) as *Microbacterium lacticum*. Few micrococci were found to survive pasteurization and the results in general show that the organisms in cleanly but not aseptically taken milk are vulnerable to pasteurization. The results were different with milk from tankers in which, after pasteurization, streptococci predominated, followed in numbers by *Corynebacterium* and micrococci. Other organisms were absent or present in very small numbers although *Pseudomonas* was found in some raw samples.

These experiments are valuable because they indicate the great influence exercised by the conditions of production and handling of the raw milk on the flora of the pasteurized milk, and emphasize the fact that there is no danger from the udder flora of the healthy cow, a conclusion of some significance.

The flora of raw milk as it reaches the plant after production at the farm under conditions which are often far from ideal, is often quantitatively large and qualitatively varied. Among the organisms surviving pasteurization in the largest numbers are the so called thermoduric cocci. Several factors determine the heat resistance of any organism but there is much evidence that bad conditions of production at the farm, such as failure to sterilize utensils and milking machines, coupled with uncleanly milking methods, result in the survival of pasteurization by large numbers of organisms so that there is nothing like the complete destruction recorded for aseptically taken milk. The survivors are streptococci, micrococci and spore formers of several types. Their survival is related also to the previous history of the milk in respect of age and temperature. The streptococci are of the *Str. lactis* and *Str. faecalis* types derived ultimately from souring milk residues, from the skin of the cow's udder and teats and from cow dung (Mattick and Neave, 1942). Their actual resistance to heat, like that of many organisms, is related to their immediate previous history. Their main activity, as far as milk is concerned, is acid formation and, when their numbers are appreciable, they cause premature souring. The micrococci which are sometimes present

in relatively large numbers in freshly pasteurized milk are usually slow acid formers, growing over a wide range of temperature, but they may have proteolytic properties as well.

The aerobic spore formers are very commonly present in pasteurized milk, usually in small numbers which are greater in winter than in summer. It appears that the shock of heating induces germination in spores which would otherwise remain dormant and, when the flora of pasteurized milk is much simplified, they may cause rapid spoilage. In recent years many cases of "broken or bitty cream" and "sweet curdling" with the rennin type of coagulation, have occurred in warm weather in pasteurized milk.

Coliform organisms, so useful in freshly pasteurized milk as an index of proper plant management, normally survive in very small numbers if at all, but it appears that occasional types, derived, for example, from dirty milking machines, may be heat resistant at least in the first generation. They may survive more frequently in foam on the holding vats and in this respect the high temperature short time process has the advantage.

The presence of heat resistant organisms in the raw milk detracts from the value of the plate count as an official measure of efficient pasteurization. My own opinion is that it is of very doubtful value for this purpose.

Plant Contamination

Unless pasteurizing plants are properly constructed and run, it is true to say that the final product may contain more organisms, often of course innocuous, than the original raw milk. This is due to the growth of thermophilic types growing at 131° F. as in the regenerator, or at 145° F. as in the holder.

The former are usually streptococci or aerobic spore bearers, the latter usually aerobic spore bearers. I have observed several instances where the milk had a keeping quality of only a few hours owing to the growth in the vats of thermophilic spore bearers. The remedy is to avoid dead ends, to keep the plant scrupulously clean and to shun runs of more than, say, $4\frac{1}{2}$ hours' duration.

My own experience of high temperature short time plants is that difficulties caused by thermophilic organisms are much fewer than in holder plants since the temperature of heating destroys vegetative forms from the regenerative section and prevents great accumulations which may seriously infect the milk (Mattick and Hiscox, 1937). Moreover, the temperature is above that normally favourable for most thermophilic organisms. It may be of interest that we have found thermophilic organisms to be remarkably susceptible to light; a short exposure to weak daylight almost sufficing to sterilize plates made to enumerate them (Mattick and Hiscox, 1936).

Contamination after Pasteurization

Apart from the pasteurizer in which the flora of the milk has been greatly reduced and normally much simplified, it is important to consider the role of pipes, storage vats, bottle fillers, capping machines and bottles. These are often difficult, and not infrequently at present almost impossible, to sterilize, and are liable to be neglected. Neglect is not likely to

impair the safety of the milk but its keeping quality will certainly suffer. Acid producing cocci, *Proteus* and coliform types are common, and such contamination greatly reduces keeping quality.

Even with the present raw milk supply, milk from the holder will keep for some 42 to 48 hours at 70° F. or for 3½ days at 60° F. Over a period of 4 years 95 per cent. of milk samples, taken from roundsmen's bottles after having passed through a well run plant, kept for at least 2½ days at 60° F. (Mattick and Hoy, 1935). Bottles above all must be properly sterilized since, as they are returned from consumers' houses, they are potentially dangerous. It is true that the main trouble is from non-pathogenic types, but my opinion is that there is much room for improvement in the design of bottle fillers and bottle washers. There still remains to be produced a really satisfactory form of the latter in which contamination from the final rinse water, a formidable source of trouble, is avoided. Suggestions for improvement have recently been made by several workers but others might well apply themselves to this important task.

The consumer has only one thing to do, to treat the milk reasonably and intelligently and keep it cool and in the dark. This is unfortunately a weak link in the chain, and without pasteurization there would be little or no liquid milk in the great towns at present.

I would like to make one final point. Evidence is accumulating that when organisms previously regarded as harmless are present in milk in large numbers they may produce irritant substances affecting the consumer. There is no need for milk at any stage of its life before delivery to contain more than very small numbers of organisms and we should bear this fact in mind and act on it in all its implications. This may mean the setting up of standard methods of control at all stages.

Conclusions

What then may be concluded from the facts given in this rapid survey? First, that in properly controlled pasteurization we have a method of rendering the milk supply safe for the consumption of the mass of the people. Second, that under present conditions pasteurization enhances the keeping quality of milk and makes it possible for milk to be generally distributed. Third, that with improved methods of raw milk production and control, coupled with improvements in the apparatus and technique of manipulating the milk after the actual heating process together with improved methods of distribution and of conservation in the home, we have the possibility of furnishing the people with a product of such superb quality as is at present visualized only by the few. To the opponents of compulsory pasteurization we may say with David, "An unwise man doth not well consider this and a fool doth not understand it"

REFERENCES

Davis, J. G. and McClemont, J. (1939). *J. Dairy Res.* **10**, 81.
Davis, J. G., Twigg, R. S. and Wright, R. C. (1941). Private communication.
Gibson, T. and Abdel-Malek, Y. (1940). *Proc. Soc. agric. Bact.* (abstracts) p. 19.
Hall, J. A. (1945). *J. Dairy Res.* **14**. In the press.
Mattick, A. T. R. and Hiscox, E. R. (1936). Unpublished observations.
Mattick, A. T. R. and Hiscox, E. R. (1937). *Int. Dairy Congr., Berlin, Sci. Rep.* **3**, 344.
Mattick, A. T. R. and Hiscox, E. R. (1939). *Med. Offr.* **61**, 177.

Mattick, A. T. R. and Hoy, W. A. (1935). Unpublished observations.
Mattick, A. T. R. and Hoy, W. A. (1939). *Proc. Soc. agric. Bact.* (abstracts) p. 27.
Mattick, A. T. R. and Neave, F. K. (1942). Unpublished observations.
Meanwell, L. J. (1927). *J. Hyg., Camb.*, **26**, 392.
North, C. E., Park, W. A., Moore, V. A., Rosenau, M. J., Armstrong, C., Wadsworth, A. B. and Phelps, E. B. (1925). *Publ. Hlth Bull., Wash.*, no. 147.
Orla-Jensen, S. (1919). *The Lactic Acid Bacteria.* Copenhagen: A. F. Høst og Søn.
Pullinger, E. J. (1934). *Lancet*, **226**, 967.
Shattock, P. M. F. (1941). Private communication.
Shattock, P. M. F. (1942). Private communication.
White, R. G. (1926). *Lancet*, **210**, 222.
Wilson, G. S. (1942). *The Pasteurization of Milk.* London: Arnold.
Zeller, A., Wedemann, W., Lange, L. and Gildemeister, E. (1928). *Z. Fleisch-u. Milchhyg.* **38**, Sonderheft 1.

The Chemical Composition and Nutritive Value of Milk and Milk Products

Dr. S. K. Kon (National Institute for Research in Dairying, University of Reading)

The Normal Composition of Milk and its Variations

The composition of milk as it is known at present is given in Table 1

TABLE 1

THE COMPOSITION OF ENGLISH PASTURE MILK

CONTENT PER 100 g.

Calories	66	Calcium	0·12 g.
Total solids	12·4 g.	Phosphorus	0·10 g.
Water	87·6 g.	Magnesium	0·01 g.
Protein	3·3 g.	Iron	0·03 mg.
Fat	3·6 g.		
Carbohydrate	4·7 g.		
Vitamin A	150 I.U.	Vitamin B_6	30 μg.
Carotene		Biotin	5 μg.
Vitamin B_1	45 μg.	Inositol	14 mg.
Riboflavin	150 μg.	Vitamin C	2 mg.
Nicotinic acid	80 to 400 μg.*	Vitamin D	2 I.U.
Pantothenic acid	400 μg.		

* Depending on method of measurement.

while Figure 1 shows the contribution of 1 pint of milk to the daily requirements of a moderately active man and of a five year old child. The calculations are based on the latest American standard (U.S.A. National Research Council, 1941), which has been so thoroughly discussed at meetings of the Scottish Group of The Nutrition Society. It is generally recognized that the value of milk as food lies chiefly in its content of protein of high biological value, its exceptional richness in calcium, and its generous supply of vitamin A, of riboflavin and of other members of the vitamin B complex. In fact one pint of milk supplies seven-eights of the calcium, over one-quarter of the protein, slightly less than one-third of the riboflavin, and just under one-fifth of the vitamin A recommended for a moderately active man. For the child the contributions are not only larger but more uniform, indicating the special value of milk for the

young. The protein is first class animal protein and vitamin A is mostly supplied as the preformed, more assimilable substance. The great value of the proteins of milk lies in their ability to enhance the biological value of the proteins of such staple vegetable foods as cereals and potatoes.

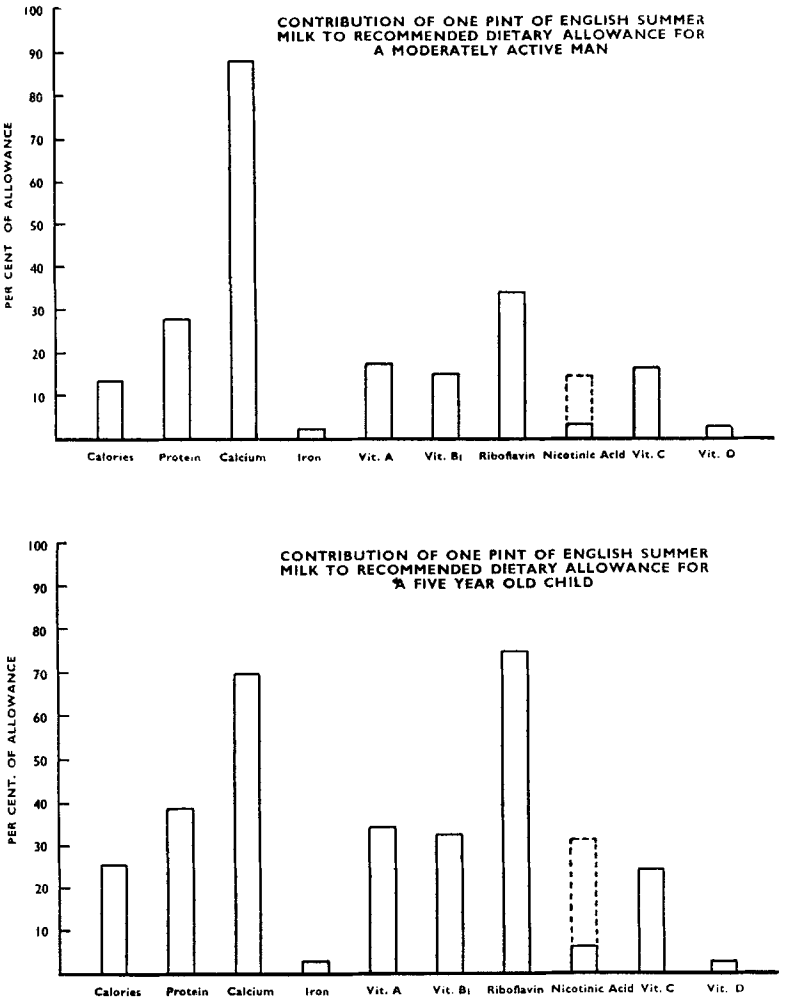

FIGURE 1. Contribution of one Pint of Milk to the Daily Requirement of a Man or Child.

Thus, for example, a combination of bread and cheese had, when tested on rats, the same biological value, 75·5, as cheese, though bread alone had a value of only 52·0; similarly a combination of milk and potato had a biological value of 86, almost as high as that of milk, though potato alone had a value of only 71. The interesting point is that if

the two substances are given separately on alternate days there is no evidence of a supplementary relationship. Old food customs thus receive scientific support.

It is probably not so well known that milk is also an appreciable source of vitamin B_1, one pint supplying one-seventh of the daily needs of the adult and one-third of those of the child. In the United States, before the introduction of enriched bread, milk was the second most important single source of this factor. Figure 1 shows also that a pint of milk could supply one-quarter of the vitamin C needed by a child. Unfortunately this does not happen in practice for reasons which will be explained later. The agreement between the results obtained with the various methods of estimating nicotinic acid in milk is far from good and it would be more prudent for the present not to rely on milk for the supply of this factor.

Finally, of iron, milk contains only negligible quantities and, as a matter of fact, an exclusive diet of cow's milk is the favourite way in the laboratory of producing nutritional anaemia in rats or mice. In this connexion a curious fact may be mentioned parenthetically. In most species the shortage of milk in iron is compensated by the body stores of the young. In the pig, however, the reserves are too small to cope with the enormous rate of growth and, even when the sow has access to the most luscious natural diet, the piglets must be given or obtain additional iron or else rapidly die of extreme anaemia.

Several reports have come lately from the United States and also from Sweden and Holland to the effect that the fat of milk is superior in nutritive value to vegetable fats. This is apparently a property of the fat itself and not of any accompanying vitamins. While not denying this possibility I must say that repeated experiments carried out at Shinfield in the last few years have completely failed to demonstrate such a difference.

Milk is a variable product and its composition, especially with regard to the so called minor constituents, varies markedly according to the season of the year and the breed, nutrition and health of the cow. The values just given apply to mixed English milk produced on pasture, and it might be instructive to outline briefly the magnitude of the normal variations and to enquire into their causes.

The calorie value of milk varies primarily with its fat content and is naturally higher for the milk of the high fat breeds, Jerseys and Guernseys, than for the milk of Shorthorns, Friesians or Ayrshires. Changes in protein, calcium or phosphorus content are normally small enough to be disregarded but fluctuations in the vitamin A activity are profound. They are mostly related to the fodder of the cow. The carotene of grass, hay, silage or kale appears in the milk partly as vitamin A and partly in its original form. In late spring, summer and autumn when grass is abundant or kale is given, the vitamin A activity of milk is at its best; in the south of England it declines steadily from November to reach its lowest point in April just before cows go out to grass. Summer milk in this country has a potency of 30 or 40 I.U. vitamin A per g. fat. In early spring the value may fall to between 10 and 20 I.U. Even at the same time of the year differences in management of the cows may produce profound variations in the vitamin A activity of milk.

We thus found last May that milk from a town dairy in Liverpool had only one-fifth of the potency of milk from a Cornish creamery. As a rule, in the milk of any one breed the concentrations of carotene and of vitamin A are roughly parallel and the degree of yellowness of the cream is a good guide to the vitamin A potency of the milk. The rule breaks down when it comes to comparisons between the milks of different breeds. The richer yellow of Guernsey and Jersey milk indicates not necessarily a higher vitamin A potency but the relative inefficiency of these breeds as converters of carotene. With access to the same pasture a Guernsey puts more carotene and less vitamin A into her milk than a Shorthorn, and the total potency per g. fat is the same for both. In the end, however, the Guernsey wins as her milk contains more fat.

The vitamin B_1 of cow's milk is remarkably independent of the feed, and is in all probability formed in the rumen by bacterial synthesis. In bulk milk the level remains more or less constant throughout the year but for individual cows it is higher in early than in later lactation.

Riboflavin content is to some extent dependent on the feed of the cow but the connexion is not clear cut since synthesis in the rumen also plays a role. Mixed milk in this country usually contains between 140 and 180 μg. per 100 ml. The milk of the Channel breeds is richer in riboflavin than that of other cattle and values of up to 250 μg. per 100 ml. may be encountered.

Information about the presence in milk of the other members of the vitamin B complex is still fragmentary, it is known, however, that pantothenic acid, vitamin B_6 and biotin are synthesized in the rumen.

Vitamin C also is synthesized by the cow but it is not known where. Certainly not in the rumen in which the relatively enormous quantities of ascorbic acid contained in fresh grass are rapidly destroyed. The level of vitamin C in milk as it leaves the udder is under effective physiological control and remains remarkably constant despite changes in season and in feeding and management of the cows. Yet in commercial milk the concentration of vitamin C is one of the most variable factors, and the consumer seldom gets more than a fraction of the quantity originally present. The explanation lies in the interesting phenomenon of induced photochemical oxidation of vitamin C by daylight. Vitamin C itself is colourless, that is, it does not absorb visible light; riboflavin, however, which is yellow, absorbs blue light and acts as a sensitizer. The effects of light are rapid and dramatic. Thus, a pint bottle of milk left on the doorstep in the usual way for half an hour and then placed in the larder loses by the time it is consumed fully half of the vitamin C originally delivered by the milkman. The destruction is in stages; under the action of light, vitamin C is transformed into dehydro-ascorbic acid, which, though still biologically active, is unfortunately unstable, and decomposes further even in darkness. There are two ways of preventing loss of vitamin C from this cause. First, exposure to light may be avoided. Cartons, for example, give a good degree of protection. Brown glass bottles would be ideal but it is very doubtful whether they would prove acceptable. Second, since oxygen is needed for the reaction its removal from milk abolishes the action of light. Much interesting work has been done on this aspect of protection in America where it is now a commercial possibility. Though the phenomenon was first observed in this country

it has elicited little practical interest, probably because the nutritive properties of milk are as yet not a selling point here.

A further factor of practical importance contributes to fluctuations in the levels of all water soluble vitamins in milk. The presence of a sub-clinical mastitis lowers appreciably their concentration and it is not unusual to observe in the same cow differences amounting to 25 per cent. between the secretions of a healthy and of a diseased quarter of the udder.

Under normal feeding conditions the vitamin D of milk is almost entirely derived from the direct action of the sun on the skin of the cow and, in summer, the sun contributes all, and the pasture none, of the increase in the vitamin D potency usual at this time of the year. During the stall feeding period a little vitamin D is obtained from hay. The vitamin D content of milk is highest around the summer solstice and falls off sharply on either side. The winter values are about 0·1 I.U. per g. fat. In summer they may be 5 to 8 times higher.

Though the normal vitamin D content of milk is much too low to be of practical value it may be increased to useful levels, and it is generally agreed that such enriched milk is most valuable in the prophylaxis of rickets. There are, roughly speaking, three distinct methods of producing such vitamin D milk, by direct irradiation, by addition of vitamin D concentrates and by feeding the cows with irradiated yeast. All three methods are used on a large scale in the United States and the irradiation of milk is becoming increasingly popular in Germany. In this country for some reason vitamin D milk has not been used to any extent.

I have made it, I hope, abundantly clear that, nutritionally speaking, milk even in the raw state is, as it reaches the consumer, a highly variable product.

Effects of Heat Treatment and of Processing

It will be apposite now to compare the extent of these so called normal variations with changes arising from heat treatment or processing of milk.

Pasteurized Milk

A large part of the commercial milk supply in this country is pasteurized, mostly by the holder method which consists in bringing the milk to 145° to 150° F. and keeping it at this temperature for 30 minutes. It has been definitely established in laboratory experiments that the only nutritive losses suffered by the known constituents of milk are a destruction of some 20 per cent. of vitamin C and of about 10 per cent. of vitamin B_1. The loss of vitamin C is largely brought about by previous exposure of the milk to light, since milk as it comes from the udder may be pasteurized without any loss. The enzymes of milk are also destroyed in the heat treatment; indeed, the destruction of the enzyme phosphatase forms the basis of the most delicate test for efficiency of pasteurization. This destruction is naturally without any nutritional significance as the phosphatase of milk would not survive in any case passage through the stomach. The high temperature short time method of pasteurization is also coming into operation here. Its effects are even slighter than those of the holder method.

Large scale experiments carried out in Great Britain in the last few

years to assess the value for children of milk, raw and pasteurized, have unequivocally shown the nutritional benefits derived from extra milk, but have failed to show any difference in this respect between the raw and heated varieties.

Sterilized Milk

In London and in some Midland centres, especially Birmingham, there is demand for the sterilized variety of liquid milk. It is convenient on account of its excellent keeping qualities, it can be bought from the grocer, and is locally popular because of the "richer" taste. This milk is heated to 212° F. and generally higher for varying lengths of time, and this drastic treatment destroys about one-half of the vitamin C and one-third of the vitamin B_1 originally present. The biological value of the proteins is also slightly decreased.

Dried and Condensed Milks

The stable, concentrated forms of milk are prepared in three different ways. The water may be removed as completely as possible, giving dried milk powder, or it is only partly removed and the condensed product is sterilized by heating to ensure bacteriological purity, or enough sugar is added during manufacture to check bacterial growth. The three methods in various modifications are applied to separated and to full cream milk.

1. *Dried Milks.* Of these three modes of treatment, drying by modern methods is generally quite mild in its effects.

Spray dried milk is obtained by forcing an exceeding fine spray of milk into a heated chamber when it dries almost instantaneously. It is nearly completely soluble in water and "reconstitutes" easily. The losses in drying are very much the same as in pasteurization, amounting to 20 per cent. of the vitamin C and 10 per cent. of the vitamin B_1 and, in addition, there is a slight deterioration in the biological value of the proteins, not exceeding 5 per cent. for good quality spray dried milk.

Roller drying consists in rapidly dehydrating a thin film of milk on steam heated, revolving metal cylinders from which it is removed by means of a stationary scraper. First quality roller dried milk is nutritionally about equal to spray dried milk, but it is less soluble in water. As a rule the loss in vitamin C is nearer 30 per cent. and the deterioration of the proteins is rather more noticeable. Occasionally specimens of spray and roller dried milk are encountered in which through exposure to naked copper during manufacture vitamin C is largely destroyed. Other milk constituents, vitamin A and carotene, vitamin D and riboflavin, suffer, as far as is known, no loss during drying. It is well established also that the availability of the calcium is not impaired by any of the treatments.

Full cream dried milks keep quite well for long periods of time in hermetically sealed containers in an atmosphere of inert gas. They deteriorate, however, on exposure to air. Modifications of the process of manufacture involving the use of a higher pre-heating temperature have recently been developed which will greatly increase the stability of milk powders (Mattick, Hiscox, Crossley, Thompson, Kon, Lea, Smith and Findlay, 1945).

Cream has proverbially been considered as the most valuable part

of the milk, and milk from which the fat had been removed has borne a stigma of inferiority. Even now, when the food value of milk is much better understood, there is still widespread prejudice against the use of dried skim milk in human nutrition. Yet, when its limitations are properly understood, it is a most valuable food. The absence of fat and of vitamin A make it totally unsuitable for babies and, in Great Britain, it must be clearly labelled to this effect. All the other important constituents remain, however, unimpaired, and, for that matter, are proportionally increased at the expense of the missing fat. The high content of animal protein, calcium and riboflavin makes dried skim milk a most valuable addition to war time dietaries. Vitamin C, vitamin B_1 and the other members of the vitamin B complex also are there in relatively increased amounts. If protected from moisture, dried skim milk keeps almost indefinitely without need for special packing.

2. *Condensed Milks.* Of the milk products from which water is removed only partly, unsweetened condensed, generally known as evaporated, milk is exposed to the more drastic heat treatment. The concentration itself is carried out at relatively low temperature *in vacuo*, but the milk is then placed in tins which are sealed, and sterilized by heat at a temperature of 240° F. This has drastic effects on the more labile components. Some 60 per cent. of the vitamin C and 30 to 50 per cent. of the vitamin B_1 are lost, and the digestibility and biological value of the proteins are slightly but unmistakably decreased. The good record of evaporated milk in the feeding of infants shows, however, that, properly supplemented, it remains a food of outstanding value.

Sweetened condensed milk is not exposed to temperatures above the boiling point of water, and the maximum temperature is frequently well below this. The development of bacteria is effectively checked by cane sugar added before condensing, the final concentration of the sugar being about 40 per cent. The losses of nutrients in this form of processing are very small and a good specimen may contain only 15 per cent. less vitamin C and 5 to 10 per cent. less vitamin B_1 than were originally present in an equivalent quantity of the raw milk.

In assessing the food value of different types of milk it should be remembered that dried milks are concentrated about $7\frac{1}{2}$ to $7\frac{3}{4}$ times in comparison with fresh milk, and evaporated milk about $2\frac{3}{4}$ times. Hence the amount of milk solids varies in the different products but the proportions of these solids remain the same. This relationship is altered, however, in sweetened condensed milk by the presence of the large amounts of sugar, and this type of milk is richer in total solids than evaporated milk, though the concentration of the milk solids is roughly the same in both.*

Effects of Heat Treatment Compared with Normal Variations in Nutritive Value

Figure 2 shows the effect of various types of heat treatment on the composition of milk, compared with the normal fluctuations in the nutritive value of raw milk caused by season, nutrition and health of the cow, or the usual exposure to light. It is clear that the amplitude of the

* As a war time measure the sale of evaporated milk concentrated only about twice has been legalized in this country.

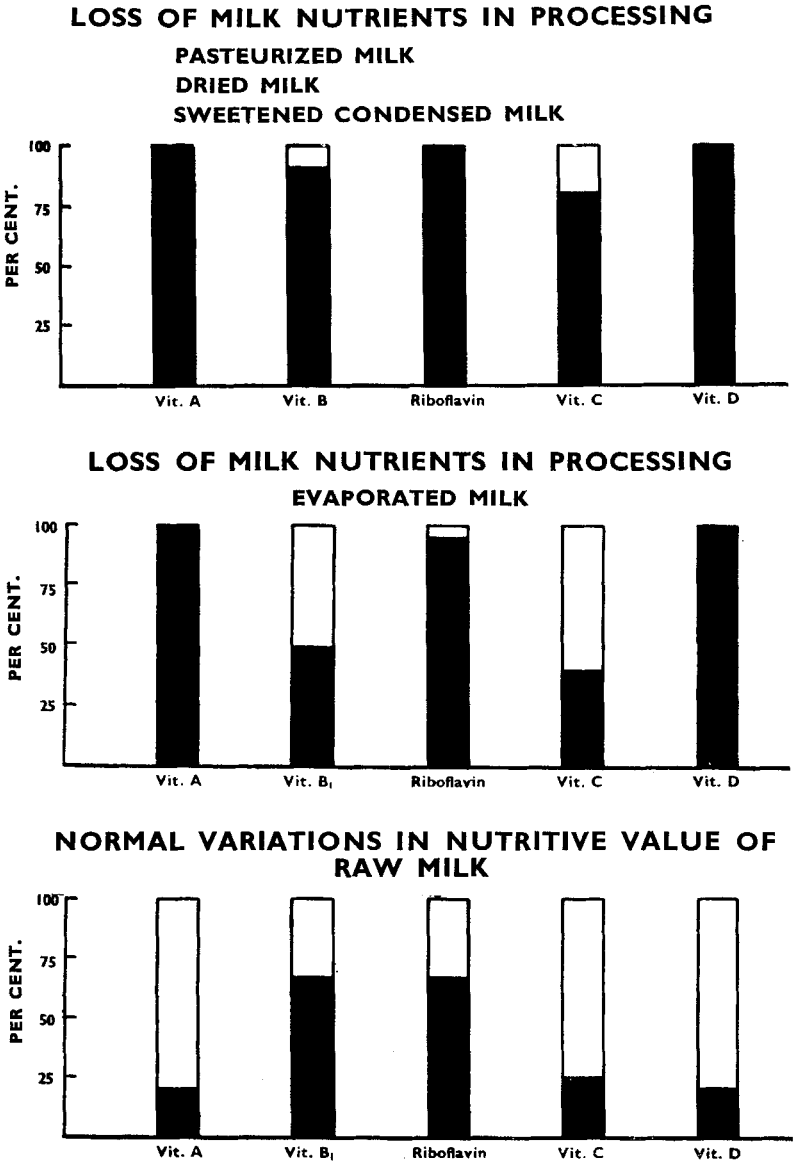

FIGURE 2. Loss of Milk Nutrients in Processing Compared with the Normal Variations in Raw Milk. White Areas Denote Loss or Extent of Variation.

variation in the raw product far exceeds the changes that are brought about by processing. It should be remembered also that as a rule the drying and condensing of milk takes place when milk is plentiful, that is

https://doi.org/10.1079/PNS19440009 Published online by Cambridge University Press

in the pasture period and that such treated milk may in fact be nutritionally superior to the raw milk available in winter time.

The Role of Milk in Nutrition

Milk occupies among foods an almost unique position in being a substance specifically elaborated and designed to satisfy the nutritive demands of rapid growth. Around the acknowledged pre-eminence of cow's milk as probably the most perfect single food of man there has grown of late a legend crediting nature with the special intention of endowing the human race with this valuable fluid. The legend would have it that as milk is a natural food any interference with the state in which it leaves the cow is harmful if not altogether sinful. Other speakers better qualified than myself have already pointed out the dangers arising from such an attitude. Sober reflection will also show that it is no more unnatural to heat cow's milk than to cook her flesh yet few people would seriously offer teleological objections to the latter procedure.

A clear recognition not only of what milk is but also of what it is not will certainly help in the just appraisal of its great nutritional merits. It is unfortunate that in winter and early spring the increased demands of the infant and child for certain dietary factors should coincide with the lowest ebb of these substances in cow's milk. It is possible to produce by dietary means winter milk approximating to summer milk in its nutritional qualities and we would do well to strive towards such a goal rather than split hairs about the alleged evils of pasteurization, an essential sanitary measure.

Agriculture in this country, whether scientific, practical or official, displays a keen interest in the forage and fodder value of agricultural products, but is only little concerned with their value in human nutrition. Feeding stuffs are produced, graded and sold according to their starch equivalent, their protein, and sometimes even their carotene, content, yet human foodstuffs are treated as if their nutritive value were of no consequence at all. There may be bad hay, indifferent hay, good hay or excellent hay, but according to pundits and legislators only one kind of fluid comes out of the cow's udder provided it contains more than 3 per cent. fat. There is now, and there was in peace time, no incentive at all for the farmer to bother about methods of increasing the carotene, vitamin A and riboflavin content of winter milk, preserving the vitamin C of milk or raising its total solids.

We have heard a lot about the marriage of health and agriculture; it is about time there was a more diligent inquiry into the nutritive value of the fruits of this union.

REFERENCES

Mattick, A. T. R., Hiscox, E. R., Crossley, E. L., Thompson, S. Y., Kon, S. K., Lea, C. H., Smith, J. A. B. and Findlay, J. D. (1945). *J. Dairy Res.* **14.** In the press.

U.S.A. National Research Council. Committee on Food and Nutrition (1941). *J. Amer. med. Ass.* **116,** 2601.

A full bibliography is given in the following reviews of the Nutritional Value of Milk and Milk Products:

Kon, S. K. (1934). *J. Dairy Res.* **5,** 250.
Kon, S. K. (1936). *J. Dairy Res.* **7,** 192.
Kon, S. K. (1938). *J. Dairy Res.* **9,** 242.
Kon, S. K. (1940). *J. Dairy Res.* **11,** 196.
Kon, S. K. (1943). *J. Dairy Res.* **13,** 216.

Discussion

Professor G. S. Wilson (London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), opener: The present state of our milk supply cannot be regarded by public health workers as satisfactory. Much of it is heavily contaminated with saprophytic bacteria and is of poor keeping quality. About 6 to 7 per cent. of farms in this country are sending out milk containing virulent tubercle bacilli, about 30 per cent., milk containing *Brucella abortus*, and an even higher proportion, milk contaminated with mastitis streptococci and other pathogenic organisms, at times derived directly or indirectly from the throat or the intestine of the milker. As a result of the consumption of this milk in the raw condition 1500 to 2000 persons die annually of tuberculosis, 400 to 500 contract undulant fever, and occasional outbreaks occur of scarlet fever, septic sore throat, diphtheria, typhoid fever, paratyphoid fever, dysentery and food poisoning, each of which we have experienced during the present war. Can we be satisfied that a nation which is generally regarded as great, and is known to be wealthy, is getting the best supply of milk? It may be getting the supply it deserves, but not the supply it needs either qualitatively or quantitatively. In these circumstances is it difficult to understand why children's physicians insist on the heat treatment of all milk? It is, therefore, most important to improve the quality of the milk.

It is an excellent thing that the control of milk has passed from the health authorities to the agricultural authorities. The latter, as experts in the subject, are much better equipped to deal with the problem. If farmers could be paid on the basis of the keeping quality of the milk we should very soon see improvement. The safety of the milk must also be improved. Tubercle bacilli and *Brucella abortus* come from the udder, typhoid bacilli from the water supply or from the imperfectly cleansed hands of persons excreting these organisms. The only satisfactory method of eliminating tuberculosis from the cows is by testing all animals in the herd, throwing out all reactors, preferably slaughtering them, and breeding only from animals free from the disease. That is possible and has been done to a very great extent in the United States. In 1917 a scheme was put into operation there which was so successful that between 1917 and 1940 the incidence of tuberculosis in cattle was reduced from 4 to 0·5 per cent. The incidence in this country is about 40 per cent., and the cattle population more crowded and more difficult to control. The task of eradicating tuberculosis here is so difficult and so expensive that we cannot hope for many years to come to supply even our needs of liquid milk with milk from tuberculin tested cows.

The bacteriological control of all personnel handling the milk is administratively too difficult. Thus the only effective and immediately practicable method of eliminating milk borne disease from the human population is by some form of compulsory heat treatment of milk, of which pasteurization is the simplest and most generally applicable. There is no evidence that pasteurization lowers the nutritive value of milk. Dr. Kon gave convincing figures to show that the change brought about by pasteurization is considerably less than the variation in composition which occurs in the milk of ordinary cows. Other objections

to pasteurization are based on erroneous conceptions. The idea that the souring organisms in milk are either natural or a valuable indication of danger is pure nonsense; but the objection that it is rather good to introduce a few tubercle bacilli into raw milk as these immunize against pulmonary tuberculosis in later life, is a much more subtle idea. There is no evidence of any correlation between the occurrence of pulmonary tuberculosis and the consumption of pasteurized milk. It is true of course that the consumption of tuberculous milk with the death of 1500 to 2000 persons annually must have some effect in the wide biological sense, as it is a matter of the survival of the fittest. What can be said of a process of vaccination which entails the death of so many people?

Where pasteurization has been introduced it brings about a striking fall in the incidence of milk borne disease and I believe it to be a practicable and immediately applicable solution to the problem of providing the public with a safe milk supply. For those who still oppose it on pseudo-scientific grounds let me cap Dr. Mattick and quote from the Book of Job: "Who is this that darkeneth counsel of words without knowledge."

Dr. G. Bourne (University Laboratory of Physiology, Oxford): I have heard it stated that the concentration of lactic acid in milk, when sour, is sufficient to inhibit the growth of pathogenic organisms; is it safe to drink milk which has become sour in this way?

Mr. H. Barkworth (South Eastern Agricultural College, Wye, Kent): Efficient pasteurization kills most bacteria but it does not reduce the acidity; milk of high acidity does not keep well, even if efficiently pasteurized, because the least bacterial action raises the acidity to souring point. With such milk improvement in keeping quality must take place at the production end; clean milk costs more to produce and, therefore, quality should be paid for.

Mr. A. L. Bacharach (Glaxo Laboratories, Ltd., Greenford, Middlesex): Those who oppose pasteurization on the ground that raw milk confers "immunity" against tuberculosis should be invited publicly to advocate the compulsory inoculation of all milk supplies with appropriate quantities of live tubercle bacilli.

The very modest consumption of 0·75 pint per head daily of liquid milk, mentioned by Mr. Davies, should not be regarded as the ultimate goal of nutritionists, since an average daily consumption of one pint by every member of the population is the least quantity that can be regarded as consonant with our knowledge of nutrition. Some continental countries considerably exceeded this figure before the war, and there is no reason why we should not do the same.

Miss D. F. Hollingsworth (Ministry of Food, Distribution Plans Division, Carlton Hotel, Pall Mall, London, S.W.1): When will it be possible to set up adequate pasteurizing plant throughout the country? Prejudice of housewives against processed milk is appreciable; therefore, propaganda on the high nutritive value of dried and condensed milk should be increased and intensified. As expenditure on milk at full retail price is relatively high, especially in working class food budgets, any suggestion that safe milk should be more expensive to the consumer than unsafe milk should be firmly opposed.

Mr. D. M. Freeland (Macfarlane, Lang and Co., Ltd., Isleworth, Middlesex): Does not irradiation of milk to enhance vitamin D tend to destroy the residual vitamin C in it?

Dr. C. A. Mawson (Royal Berkshire Hospital, Reading): The ascorbic acid content of milk is so small that it is not important as a source of vitamin C in the diet. The destruction of this vitamin by pasteurization is not, therefore, a matter of any practical importance, even for infants who in any case obtain vitamin C from other sources.

Mr. J. Francis (Foot and Mouth Disease Research Station, Pirbright, Surrey): Dr. Mattick mentioned the need of pasteurizing milk and milk products used for animal feeding. It is of some interest to recall that it is just 50 years since the Danish veterinary authorities introduced regulations providing for the compulsory pasteurization of all milk by-products returned from the dairies for animal feeding. The regulations of the Tuberculosis (Attested Herds) Scheme (England and Wales), 1937, also provide that any milk or milk product brought to the premises of an attested herd for feeding the animals must come from the premises of another attested herd, or be pasteurized.

Not only have veterinarians realized the dangers of giving raw milk to animals but, as long ago as 1901, when controverting Koch's view that bovine tubercle bacilli are not pathogenic for man, Sir John M'Fadyean advocated the heat treatment of milk destined for human consumption.

Dr. N. S. Barron (Veterinary Investigation Department, The University, Reading): To those who argue that drinking milk containing live tubercle bacilli has the merit of immunizing a proportion of those who consume it, an effective reply would be to ask them whether they would give their own children a vaccine which might on the one hand give protection against tuberculosis, but might also infect them with the disease with possibly fatal results.

Dr. D. W. Kent-Jones (Dover Laboratories, 88 Madeley Road, Ealing, W.5): Although there is undoubtedly an increase in the consumption of liquid milk since the war, has there been any increase in the total production of milk, bearing in mind the smaller amount of milk now allocated for manufacturing purposes?

Dr. A. T. R. Mattick gave the following replies:

To Dr. Bourne: Milk taken straight from the holder of an efficient pasteurization plant keeps for $3\frac{1}{2}$ days at 60° F. Ninety-five per cent. of milk taken from roundsmen keeps for $2\frac{1}{2}$ days at 60° F. Neither pasteurized nor any other type of milk should be allowed to go sour. It is not dangerous to drink milk that has become sour through the action of lactic streptococci.

To Miss Hollingsworth: Pasteurization could come to pass in the larger towns and in many of the smaller ones tomorrow, if permission was given.

Dr. S. K. Kon gave the following replies:

To Mr. Bacharach: I would probably not ask for a daily pint of milk for each adult but certainly for every pregnant and lactating woman and for children.

To Miss Hollingsworth: Full information about the high nutritive value of processed milk has been published; it is for the Ministry of Food to disseminate it, if this is desirable.

To Mr. Freeland: Ultraviolet irradiation of milk need not destroy vitamin C. With modern plant the time of exposure is very short, it is also possible to exclude oxygen and thus afford a large measure of protection.

To Dr. Mawson: Milk is potentially a good source of vitamin C, as it contains originally 12 to 15 mg. per pint; it would be well worth while to aim at retaining this quantity in milk as it reaches the consumer.

Chairman's Summing Up

Professor H. D. Kay (National Institute for Research in Dairying, University of Reading): The discussion has emphasized that there are three partners to be considered in questions affecting milk, the producer, the distributor and the consumer, each with different interests but of which none should be forgotten. Even when improved training for those engaged in the industry is being advocated, it should not be overlooked that the consumer equally requires improved knowledge of nutritional values.

As regards the producer of milk, Mr. Davies has indicated something of the national indebtedness during the war to the dairy farmer who, despite war difficulties, has maintained, and even increased, his production to meet the increasing need for milk. Mr. Davies is himself playing a very important part in the development of the producer's side of the milk industry.

We now have a scheme for the rationed feeding of dairy cows, in which the Ministry of Agriculture and the Ministry of Food are both intimately concerned. It is clear that, though a war measure, this scheme must remain in some form after the war, at least until the national supply of milk is assured under peace time conditions. Food, health and agriculture must remain in close touch after the war as regards the human population of this country. They must likewise work together both now and after the war for the benefit of our farm animal population, particularly the dairy cow. Schemes for livestock improvement, arrangements for control and elimination of disease in dairy herds, arrangements for feeding in accordance with yield which entail milk recording, cropping for milk production, milk testing and advisory schemes, must go forward together.

All three of the partners are concerned that the pasteurization controversy should cease. All milk sold for human consumption must come from healthy herds or be heat treated, and we shall not see the increase in milk consumption that we ought to see and which everyone at this meeting hopes for until this is the law. Legislation of this kind, though opposed by some short sighted producers, would really help the dairy farmer, as there would be a greater demand for his milk when it was generally realized that all milk was now safe.

From the standpoint of the nutritive value of milk we have still a long way to go in both production and handling methods before we obtain what Dr. Mattick has described as "a product of such superb quality as is

at present visualized only by the few." Milk is too variable in nutritive value. These variations are partly under the control of the farmer. If milk were sold on a basis of volume and keeping quality, with no real regard for its nutritive value, then cows giving a large volume of milk at the lowest physiological cost to the animal, that is to say, milk of increasingly poor composition, would give the greatest financial return to the producer. It is clear from the discussion today that, in the future, as well as a standard of safety, a standard of nutritive value, related to what the healthy, properly fed and managed average cow can produce, should be laid down.

We shall have to consider how milk consumption per head shall be increased to the level our nutritional advisers agree is desirable. Better training for all three of the partners concerned, not only producers and distributors but also consumers, should be a part of our general educational policy. As a start every schoolboy and schoolgirl who for present purposes can be regarded as a future producer, distributor or consumer of milk, should have during the last three or four years at school, not less than one day a week of instruction in the fundamentals of science. In this time something should have been learnt not only of nutritive values but also of the scientific principles on which most of our adult activities in a modern world are founded.