FOOD YEAST

By F. O. READ

Since time immemorial, man has been striving to discover the underlying requisites for robust health. The importance of the diet was almost immediately realized, but just how and to what extent it was involved, has taken centuries to discover, and even to-day, the picture is by no means complete.

At first the emphasis was on heat producing foods which supplied the calories necessary for an active life. Later it was discovered that these were not enough to ensure health—the importance of vitamins was established. Of still more recent date was the discovery that proteins too, have an essential part to fulfill in the diet.

Man has two general sources of protein at his disposal, viz. animal and vegetable, and it is now generally accepted that animal protein is superior to vegetable protein.

Proteins are mixtures of very complex chemical substances, many of which have not yet been isolated, but they are known to contain at least a score of amino acids. Proteins from vegetable sources are often deficient in some of these essential constituents, which detracts form their nutritive value.

To obtain the full value of the proteins, carbohydrates and fats in the diet, certain vitamins must also be present, amongst others the vitamin B group. This also is a very complex mixture containing at least ten constituents and occurs naturally with protein in milk, meat, eggs, etc. Here again animal sources provide a better balanced vitamin B, as that derived from vegetable sources is often deficient in certain essential constituents.

Thus it follows that persons living largely on a vegetable diet, are liable to suffer from a deficiency of good proteins and vitamin B.

It is true that certain animals that live entirely on a vegetable diet, are capable of producing these missing proteins and vitamins within their own bodies. Human beings are not so fortunate and have to rely on an extraneous source.

During comparatively recent times, the important discovery was made that yeast can supply all the constituents necessary to complement the vitamin B group as it occurs in vegetable sources. Moreover it so happens that yeast is an excellent source of protein, of the same high nutritive value as animal protein.

Of course, for centuries past, our ancestors have unwittingly been making good the deficiency of proteins and B vitamins in their diets by consuming large quantities of freshly prepared mead and beer for instance. The natives of Africa had their traditional Kaffir Beer pot, etc. These beverages underwent none of the refinements applied to modern wine and beer and retained in the dregs large numbers of yeast cells. With the progress of civilisation, these old established items of diet gradually disappeared, to be superseded very often by refined wheaten products, mealie meal, polished rice, etc. As a result the general health of the community gradually deteriorated and very often deficiency diseases ensued.

If yeast is again to be used in the modern diet, presumably a practical method of application would be to admix it with the wheaten products, mealie meal, etc. For this to be economic, a large supply of good quality yeast at low price must be forthcoming. At present brewers' yeast is in very short supply and moreover this yeast is most unpalatable, due to its extremely bitter taste and also due to the large percentage of insoluble calcium salts, with which it is usually mixed. The only other yeast commercially available is bakers' yeast, which has a blander taste. This however is grown for a specialized purpose, on an expensive batch process, and would be far too costly for general application.

In an endeavour to be self sufficient, the Germans started producing food yeast about 30 years ago. Unfortunately little information is available as to what measure of success was achieved, from the physiological aspect. It is, however, significant that production on a large scale was continued right up to the time of capitulation in 1945. It may further be noted that the Germans used the expensive wood saccharification process to provide the source of carbohydrate for yeast growth.

In 1940, the British Colonial Office decided to sponsor the production of food yeast, and Dr. Thaysen of the Department of Scientific and Industrial Research was asked to investigate the problem.

As the source of carbohydrate, Dr. Thaysen chose molasses, which in normal times is available to the British Empire in abundant supply, at a very cheap price. He then set about developing a suitable strain of yeast. For this purpose the yeast chosen should have the following properties:

(i) It should grow well on the sugars in molasses and should at the same time produce a high yield of food yeast.

(ii) The dried product must be palatable.

(iii) It should have a high rate of growth which would effect an economy on the size of plant necessary.

(iv) The cell size should be large enough to enable efficient handling with the machinery commercially available.

(v) It should be capable of growing at a reasonably high temperature, as this would facilitate cooling in warm climates.

(vi) It should be capable of withstanding storage in the cream form, for short periods at ordinary temperatures without autolysing (yeasts have the property of being able to feed on themselves in the absence of other foodstuffs—a process known as autolysis).

After some lengthy research, Dr. Thaysen succeeded in developing an entirely new strain of yeast which he named *Torulopsis utilis* variety major, which more nearly satisfied all the above requirements than any other strain examined. For instance, it was capable of growing approximately three times as rapidly as bakers' yeast under optimum conditions. Furthermore, with the exception of phosphorus and nitrogen, which can be supplied in inorganic form, this yeast can obtain all the nutrients required for growth, from molasses.

Next he set about devising a continuous process. The batch process, whereby bakers' yeast is normally produced, would be far too costly on the scale visualized for food yeast. As the result of experience and data gained on a pilot plant at Teddington, a commercial factory designed to produce 4,000 tons per annum was subsequently erected in Jamaica. Inevitably difficulties were encountered calling for minor changes of design and variations in the process, etc. This greatly hampered production but it is believed that the plant will soon be in full operation.

Samples of food yeast produced by the pilot plant at Teddington were subjected to various tests which proved fairly conclusively that the addition of food yeast greatly improves the nutritive value of a diet whose protein is otherwise derived mainly from cereals. The biological value of the mixture of the cereal proteins with those of yeast, is equal to that of a similar mixture using milk protein instead of yeast. Trials undertaken showed that at least ½ oz. could be taken daily without risk of digestive disturbance. This amount may seem negligible, in that it would increase the *amount* of dietary protein by only ¼ oz. daily, but by supplying the amino acids normally missing in the proteins of cereals, it nevertheless disproportionately improves the quality of the protein in a diet composed largely of cereals.

A report on nutritive tests conducted along these lines in the United Kingdom, can be found in an official British publication—British Medical Research War Memorandum No. 16 (1945). In general, the results of these tests were very favourable and in no cases were harmful effects observed.

In South Africa at the instigation of the Ministers of Public Health and Economic Development, the Food Yeast Development Co. (Pty.) Ltd., was formed with two objects in view, viz.:—

(*a*) Investigating the possibility of producing food yeast in South Africa from raw materials available locally and to determine the costs of manufacture.

(*b*) Should production be feasible, to provide sufficient food yeast to enable its nutritive value to be tested systematically in South Africa.

Some preliminary work was initially undertaken using a laboratory size generator, and a pure culture of *Torulopsis utilis* variety major, obtained from London. This strain of yeast has been patented, and the Industrial Development Corporation hold the patent rights in the Union. Subsequently a semi-commercial plant with a nominal capacity of four to five tons per month was designed and erected at Merebank. Here again considerable difficulties had to be overcome primarily as the result of the lack of suitable equipment during the wartime. Of necessity much of the plant installed was of a make-shift character of local fabrication, especially as it was deemed essential to operate this plant on the continuous process only. Minor alterations have been effected from time to time, but basically the process has remained unaltered. The various stages of the process will be described in outline.

Molasses Pretreatment.

Molasses is diluted with an equal proportion of water, by weight. Sufficient sulphuric acid is then added to give a pH of 4.0. The solution is boiled by means of live steam, in an open vat for one hour and then allowed to stand for 24 hours. Calcium sulphate in the form of gypsum gradually settles out and carries down with it, most of the suspended organic matter. This step is essential for two reasons (*a*) too large a concentration of calcium salts in solution has a deleterious effect on the growth of yeast and furthermore might cause precipitation of calcium salts in the generator and so adulterate the final food yeast product. (*b*) Unless the organic matter in suspension is removed, it imparts a very dark colour to the yeast. By means of a float, the clear solution is drawn off from the top, leaving the sediment behind. As an additional precaution the solution is next passed through a centrifugal to ensure complete clarification and stored in vats ready for use in the generator. The percentage of sugars present is determined by the Fehling's reduction method—it normally averages about 25 grams sugar per 100 ml. solution.

Generator.

This consists of a stainless steel vessel fitted with water spraying pipes, for external cooling and an overflow pipe which can be adjusted to any desired working volume. Air is introduced at the base through porous ceramic candles having a pore size of about twelve microns. Suitable instruments are fitted for metering the volume of molasses, ammonia, phosphoric acid and water to be added, and for recording the pH and temperature of the contents of the generator.

Before proceeding with an outline of the procedure adopted, there are several general considerations which should be borne in mind.

(*a*) It is a general property of yeasts that the production of alcohol is favoured by a high carbohydrate concentration and anaerobic conditions. Conversely the propagation of the yeast itself is favoured by extremely low concentrations of carbohydrate and an abundant supply of oxygen in solution. In practice the latter is achieved by passing air into the liquor, through porous candles previously mentioned. By thus breaking up the air into minute bubbles a large surface area is provided which facilitates solution of oxygen in the liquor. By this method a considerably higher percentage of the oxygen passes into solution, than if perforated pipes are employed, as is established practice, in the manufacture of bakers' yeast. By calculating the theoretical amount of sugar that the yeast could consume hourly if growing under optimum conditions and adding it accordingly, the carbohydrate concentration is kept as low as possible.

(*b*) The optimum hydrogen ion concentration for this particular strain of yeast is between pH 4 and pH 5.

(*c*) The optimum temperature is 36 to 37°C., and as approximately 1,600 B.T.U. are liberated for each pound of sugar oxidised, it is necessary to cool the generator in order to maintain the temperature between these limits.

(*d*) It should be constantly borne in mind further that should the conditions of growth depart much from the optimum even for a short period only *e.g.*, as regards hydrogen ion concentration or temperature the yeast may become permanently weakened, and although optimum conditions are subsequently re-stored, it may never again regain its former activity. Obviously therefore extremely careful and regular control is essential.

(*e*) Great care is required at all times to guard against possible infection. All plant has to be thoroughly sterilized at regular intervals, all liquids fed into the generator should be absolutely sterile and the air used should be efficiently filtered.

To proceed: to start the generator a certain amount of sterile water, dependent on the weight of seed yeast available, is run in. Sufficient seed yeast is added to give a wet yeast concentration of about one per cent. This is determined by centrifuging fifteen mls. of the liquor, in a laboratory centrifuge, using a calibrated tube. The total weight of yeast in the generator can then be calculated from the volume of liquid and the yeast concentration. From this, the total amount of nutrients to be added is calculated as follows:—

Assume the weight of yeast present is ten kg. It is known that the generation time of this strain of yeast is less than 100 minutes, and consequenty if this weight of yeast were grown under optimum conditions, it should be capable of increasing in weight by about five kgs. during the following hour. Therefore sufficient nutrients should be provided during the hour, to grow five kgs. of new yeast. It is known that one kg. of yeast requires 0.4386 kgs. sugar, 0.00526 kg. phosphorous and 0.02113 kg. nitrogen. Consequently by simple multiplication it follows that the weight of nutrients required is 2.193 kg. sugar, 0.0263 kg. phosphorous and 0.1056 kg. nitrogen.

The pH is watched carefully and should it exceed the optimum limits, it is adjusted by the addition of either sodium carbonate or sulphuric acid, as the case may be.

The nitrogen content is determined every fifteen minutes by the rapid formol titration method, which affords a ready check on the rate at which nitrogen is being consumed, and hence the rate at which the yeast is growing. At the end of the hour, the yeast concentration is determined again and as before the total weight of yeast present is calculated. If it has grown according to schedule, then there will be 15 kg. present, and during the following hour sufficient nutrients should be added to grow 7.5 kg. of new yeast and so on.

This process, whereby a larger quantity of yeast is grown each hour, is termed the differential growth of yeast and is continued, until the yeast concentration reaches 9 per cent. Experience shows that yeast does not grow well at concentrations in excess of 9 per cent., probably due to overcrowding. On a batch process, once this stage is reached, the yeast is harvested, the generator is emptied and a new differential is started. Obviously the time taken to reach a concentration of 9 per cent. is dependent on several factors, but it is normal on a batch process, for the the differential to last about twelve hours.

Assuming that 10 kg. of yeast were used as inoculant and that an hourly growth rate of 50 per cent. was maintained throughout the twelve hours, then the final weight would be about 1,300 kg.

But if the process could be continued for another hour, presumably it should be possible to produce another 650 kg. of yeast. And if the process could be be continued indefinitely it should be able to produce 650 kg. of yeast every hour. This in fact is the essence of the continuous process whereby it should be possible to produce 1,300 kg, of yeast in 2 hours as against twelve hours by the batch process, using the same size generator. The Food Yeast Development Co. has devoted its energies exclusively to continuous production, production by a batch process not having been attempted. Continuous production is achieved by calculating the nutrients required for the following hour by the same method as before. But now it is necessary to add water as well in order to accommodate the new yeast grown at a concentration of 9 per cent. *i.e.* if 650 kg. of yeast are to be grown, and the concentration is to remain at 9 per cent., the volume should be increased by $\frac{100}{9} \times 650 = 7{,}222$ litres. From this figure is deducted the combined volume of the sugar solution, the ammonia and the phosphoric acid to be added, to obtain the volume of water required. The rate of flow of all these liquids is then adjusted to the calculated figure using the flowmeters previously mentioned. In this example the generator has been assumed to contain 1,300 kg. of yeast at a concentration of 9 per cent. *i.e.* the volume of liquid is $\frac{100}{9} \times 1300 = 14{,}444$ litres.

Thus the overflow pipe would be adjusted to a working volume of 14,444 litres and any liquid in excess of this would automatically run out.

The yeast concentration is determined each hour as previously, and should it vary the amount of nutrients added are altered accordingly.

Throughout the above, it has been assumed that the yeast will increase in weight at a steady hourly rate of 50 per cent. In practice, of course, this is very difficult to attain, though rates of growth approaching 50 per cent. have been achieved.

In spite of all the precautions taken, infection troubles have been experienced, which sometimes limit the duration of the continuous phase to less than a week.

Concentration and Washing.

The yeast liquor runs out of the generator continuously and is passed through a yeast separator, which concentrates it to about 50 per cent. yeast. This cream is then diluted again with water to approximately the original volume and again passed through the separator. This washing procedure is repeated two or three times until the waste water is perfectly clean.

Drying, Milling and Bagging.

The yeast cream is dried on a double drum drier to about 5 per cent. moisture. It emerges from the drier in a flaky form and is put through a hammer mill to break it up into a fine powder, to facilitate bagging. It is stored in 50 lb. paper lined bags. The dried product is slightly hygroscopic, but if suitably stored will keep almost indefinitely.

Using as a standard, the figures published by the Colonial Food Yeast Development Co., the nominal capacity of the Merebank plant is four to five tons monthly. It is now producing regularly at seven tons monthly and some further increase is likely.

Seven tons monthly corresponds to about 610 lbs. of food yeast per working day, and since the total capacity of the single generator is 83 cubic feet, this is equivalent to 7.3 lbs. food yeast per cubic foot of generator capacity per day. The Jamaica plant was designed for an output of only 5.6 lbs. per cubic foot of generator capacity while the full production capacity of German plants was less than 0.6 lbs. per cubic foot of generator capacity.

It is therefore evident that the technique of food yeast production evolved at Merebank is not only equal to, but probably superior to methods in use elsewhere.

It can safely be said that the first object of the Food Yeast Development Co., has been achieved, in that the technical difficulties in the production have been mastered.

It is of interest to note that large quantities of food stuff of excellent nutritive value, can be produced largely from a product of which there is normally a surplus over and above Union requirements. Furthermore by growing, say sugar, on a given acreage of land, and using this sugar plus a small amount of phosphate and ammonia to grow yeast, a yield of protein can be obtained, which is several times as high as could be obtained directly by growing the best protein producing agricultural crops on the same acreage, and many times higher than the protein which could be obtained from animals fed entirely off a similar acreage.

In furtherance of the second object, practically the entire output to date has been placed at the disposal of the National Nutrition Council, who are conducting a series of tests to evaluate its nutritive properties. Although the value of food yeast has been clearly established by nutritive tests conducted in the United Kingdom and elsewhere, it is considered advisable to carry out further tests under South African conditions, as a check. For obvious reasons these tests to be conclusive, should be of fairly lengthy duration. The outcome of these tests is still awaited.

The PRESIDENT said he welcomed this paper because, as technologists, we were most interested in the by-products of sugarcane. Higher efficiencies were often claimed in other countries than were obtained here, but in this paper it was stated that in the conversion of molasses into yeast some of the best efficiencies in the world had been obtained in the local pilot plant.

Mr. DU TOIT said that the author claimed that 1 ton of yeast could be obtained from 0.4386 tons sugar, but that was of course not dry yeast, but wet yeast containing about 50 per cent. moisture and 25 per cent. protein. Even at this figure, however, assuming that we could recover 3.5 tons of sucrose per acre every second year, the annual yield of protein would be about one ton per acre.

According to C. A. Brown in Industrial and Engineering Chemistry (New Edition, 1943), the Germans obtained about 34 kgs. yeast from 200 kgs. molasses in the first world war, using the Delbrück process. This yeast contained about 47-56 per cent. protein, but on account of the loss of energy some German dieticians considered the feeding of the molasses to animals directly more economical, and the process was found to be uneconomical after the first world-war, as it could not compete with the production of other protein concentrates. He noticed that the loss in energy in the process now being used at Merebank was also very considerable.

Apart from the protein value, food yeast was also very valuable as a rich source of vitamin B. He was under the impression that it contained about 20 parts per million aneurin, 60 parts per million riboflavine, and about 500 parts per million nicotinic acid; but he had not seen any vitamin analyses of South African food yeast, and would be interested in any such figures which the author might have. He had seen a reference to the fact that lack of iron stimulated vitamin B production in toralopsis utilis, and would like to know what other effect iron had on the production of food yeast.

Mr. READ, in reply, stated that he considered the yield of 34 kgs. of yeast from 200 kgs. molasses, as obtained in Germany during the first world-war, was very low. At Merebank a yield of one ton of food yeast was obtained from 4.5 to 5 tons of molasses and theoretically even less should be used; but there was, of course, the loss of energy referred to by Mr. du Toit. Theoretically, a 60 per cent. conversion of sugar to yeast should be obtained, but in practice only 45 per cent. was realized.

Large quantities of iron and even calcium had a very bad effect on the growth of yeast, but he could not say what the effect on vitamin B formation was. He had, in fact, no data on the vitamin B content of South African food yeast, as it was difficult to get the analyses done here. Arrangements had now been made, however, to get it analysed overseas.

Mr. HAYES said that he could not see how an organism such as a yeast could be patented, as was claimed in this paper. He also mentioned the fact that the production of food yeast was not confined to the Merebank pilot plant. Messrs. Dehydrated Products, of Johannesburg, had been in production for some time. Their output was about 8 to 10 tons per month and the average yield, he believed, was about 40 to 45 per cent. on sugar. The yeast had been assayed regularly at the Institute of Medical Research and the vitamin content was found to be slightly higher than that claimed for the overseas product.

Mr. READ stated that the yeast strain used at Merebank was not a naturally occurring one, but was the result of laboratory research in England.

He was aware that food yeast was being produced in Johannesburg, but the process used was the simple batch process which, unlike the continuous process, did not call for any special research or technique in handling. For large-scale production the batch process could not, however, be compared with the continuous process.

Dr. HEDLEY congratulated Mr. Read on the results achieved, which he appreciated because he started the process at Merebank and knew of all the difficulties that had to be overcome. The pilot plant was put down in an alcohol distillery, which was probably the worst place for such a plant. The walls of the room and the atmosphere were very badly infested with all kinds of infection, and the process often broke down after a short run. The use of the aeration candles was made difficult by the excessive amounts of foam formed.

Mr. READ agreed that the pilot plant was erected in a very bad place, but he thought if the process worked here, it would probably work anywhere else. Infection was, of course, the big trouble, but even that had been cut down considerably, and it was now possible to work continuously for about eight days or, in exceptional cases, up to eleven or twelve days. The foaming problem was largely tied up with the infection problem. If infection were eliminated, not much trouble would be experienced with foaming.

Dr. DODDS said that the present world requirements of sugar were in the neighbourhood of 35 million tons, but would be increased to 100 million tons if every human being could get all the sugar he required. The latter figure was, however, the ceiling at present for direct consumption of sugar, but if sugar could be economically utilised for food yeast production or in other important ways it would open up new possibilities for the sugar industries of the world.

Mr. Read stated, in reply to Mr. Duchenne, that food yeast was of much the same food value as bakers' yeast or any other yeast; but whereas it was estimated that a pound of dry food yeast produced from molasses in a 40,000-ton per annum plant cost about 6d. a pound, wet bakers' yeast costs about 4s. or 16s. a pound of dry yeast.

The yeast strain used in the production of food yeast formed invert sugar from sucrose very readily, but the alcohol was only formed to the extent of one to two per cent.