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The Chemical Preservation of Food

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THE first question which has to be answered is—Why do we want to preserve food? The Director General of FAO recently said: "One half of the world's population suffers from lack of food adequate in quality and quantity to sustain their health, growth, and physical vigour". With the world's population at 2,700 millions, increasing by 1·7 per cent per year, we must not only increase the amount of food we produce, but preserve as much as we can from needless spoilage. Food preservers are modern Josephs evening out the fat and the lean years.

In addition preservation copes with the problem of the growth of large industrial areas. The complexity of modern life and changes in our eating habits required us to find methods of preserving foods which our ancestors used to eat fresh or freshly cooked.

Variety is given to the diet at different times of the year, and a wide choice is available to the consumer. Further, a stockpile of food is available to cope with emergencies. Food can be bought in areas not suitable for food production, far from the areas of cultivation. Finally, it is easier to satisfy nutritional and quality requirements owing to the wider variety of food available.

Most foods are subject to attack by moulds, fungi and bacteria. Some foods do not need methods of preservation. Foods like cereal grains, nuts, seeds, etc., keep well. Some others keep for a few months—root vegetables, potatoes, flour, dried fruits, some fruits such as apples, fats—including butter. The over-riding reason for this is the low-moisture content of these foods. Other foods of higher moisture content do not keep so well, and it is necessary to make some attempt at preserving them if the foods are not to be destroyed by micro-organisms.

There are various methods of preservation; sterilisation by heat, freezing, dehydration, aseptic methods, chemical methods. Of these methods, chemical methods are of increasing importance.

I think we can define a chemical preservative simply as a substance that is added to food to prevent spoilage. This would include in our scheme such things as sugar and salt as well as antibiotics, and other chemical compounds used in the food industry, as shown in Table I.

TABLE I

PRESERVATIVES USED IN FOOD

Group I. The Traditional Preservatives

Sugar	Spices
Salt	Mustard oil
Saltpetre,	Products of Smoking
Nitrites	Alcohol

Group II. Acid Preservatives

Acetic acid
Benzoic acid and benzoates
Dehydro acetic acid
Sorbic acid
Propionic acid and salts
Boric acid
Sulphur dioxide and sulphites

Group III. Antibiotics

Chlortetracycline
Oxytetracycline
Subtilin
Nisin

Legal Considerations

The Food and Drugs Acts 1955 and 1956 control the addition of substances to food. They make it an offence to add a substance to food so as to render it injurious to health, or to sell food not of the nature, substance or quality demanded. The Preservatives Regulations 1925, at present only permit the use of a very limited number of preservatives in prescribed foods. No restriction is imposed on the use of such substances as sugar, salt, acetic acid or vinegar, spices, alcohol, saltpetre, or substances introduced to food as a result of smoking.

(1) *Sulphur dioxide* (and sulphites) may only be used as preservatives for certain stated foods; in such cases, they are permitted up to certain prescribed limits ranging from 70 parts per million for syrups and mineral waters up to 3,000 p.p.m. for cherries and cherry pulp. See Table II.

TABLE II

FOODS PERMITTED TO CONTAIN SULPHUR DIOXIDE

Food	*Maximum permitted Sulphur Dioxide (parts per million)*
Sausages and sausage meat ...	450
Fruit pulp for conversion into jam, crystallised, and glacé fruit:	
Cherries ...	3,000
Strawberries and Raspberries ...	2,000
Other fruit ...	1,500
Dried apricots, peaches, nectarines, pears ...	2,000
Dried raisins and sultanas ...	750
Fruit juices and cordials; non-alcoholic wines ...	350
Jam; crystallised and glacé fruit ...	100
Sugar and syrups ...	70
Cornflour and starches ...	100
Corn syrup (liquid glucose) ...	450
Gelatine ...	1,000
Beer and sweetened mineral waters ...	70
Cider ...	200
Alcoholic wines ...	450
Dehydrated potatoes ...	550
Dehydrated cabbage ...	3,000
Other dehydrated vegetables ...	2,000

(2) *Benzoic Acid and benzoates* are allowed as preservatives for fruit juices, mineral waters, coffee extract, pickles and sauces. The maximum amounts permitted vary from 120 p.p.m. for mineral waters to 2,000 for grape juice and non-alcoholic wine. See Table III.

TABLE III

FOODS PERMITTED TO CONTAIN BENZOIC ACID OR BENZOATES

Food	*Maximum permitted benzoic acid (parts per million)*
Unfermented wine or grape juice	2,000
Fruit juices and cordials; non-alcoholic wines	350
Sweet mineral waters	120
Brewed ginger beer	120
Coffee Extract	450
Pickles and sauces	250

(3) *Nitrite* (sodium or potassium) is allowed in bacon, ham, or cooked pickled meat. Cooked pickled meat (not bacon or ham) may contain up to 200 p.p.m. as $NaNO_2$. Nitrite for curing hams and bacon is only permitted under licence. The licence fixes limits for the pumping pickles and immersion brines, but not for the finished product.

(4) *Diphenyl* and o-phenylphenol are used on wrappers for fruits to prevent mould action on the fruit surface. Most of the phenolic substance volatilises, but traces may be found as residues, and maximum limits are therefore imposed. See Table IV.

TABLE IV

FOODS PERMITTED TO CONTAIN DIPHENYL AND O-PHENYLPHENOL

	Maximum permitted (parts per million)	
	Diphenyl	*o-phenylphenol*
Citrus fruits	100	70
Apples, pears, pineapples	—	10
Peaches...	—	20
Melons	—	125

At the moment, all other chemical preservatives not naturally occurring in foods are prohibited; but the Food Standards Committee's Sub-Committee on Food Preservatives has recently issued a report which has recommended that a number of concessions be made to extend the number of permitted preservatives, and the foods in which they may be used.

TECHNICAL ASPECTS

Group I.—The Traditional Preservatives

Sugar. This is the most widespread chemical preservative. It may be in the form of sucrose, or any other sugar or combination of sugars. Sugar preserves food because of the strong osmotic pressure at concentrations of 65 per cent and over calculated on the aqueous phase dehydrating the spores of the invading organism. It is by this action that jams, jellies, sugar confectionery, condensed milks, boiled sweets, and similar foods do not spoil.

Salt, saltpetre, nitrite. Salting is one of the oldest methods of preserving meat, fish and vegetables. Again, the salt acts by its osmotic effect which inhibits bacterial enzymes, as well as those enzymes naturally present in the food.

Fish may be cured in tanks of strong brine (21–23 per cent) for 2–3 weeks, and is also usually salted before smoking.

Salted pork helped to build up the British Navy, but dependence on such foods to the exclusion of fresh fruit and vegetables also helped in the spread of scurvy.

In bacon and ham curing[27], salt is used along with sodium or potassium nitrate or nitrite. The mixture known as the pickle may be injected under pressure ("pump pickle"), and the sides of bacon are then placed in a tank of "mature pickle", a strong solution of salt, saltpetre and nitrite (added as such or formed by bacterial action from the saltpetre).

The salt and saltpetre narrow the range of micro-organisms which can grow on the surface, and decrease their rate of growth. The drier the surface the greater is the concentration of the salt, and its effectiveness. On a fairly dry surface, York ham for instance, a green mould such as Pencillium can form; this in turn inhibits the growth of bacteria and the development of oxidative rancidity.

Nitrite is only needed to the extent of several parts per million in order to produce sufficient nitroso-myoglobin for the characteristic red colour of cured meats. Until recently this was all—it was not regarded as having anti-microbial action. It has been shown recently by Eddy[29] that under the actual conditions of *p*H, etc., nitrite can have an important effect in inhibiting some of the bacteria which cause spoilage in cured meats.

Smoking whether of fish or meat, affects the colour and flavour; but also deposits various chemicals such as formaldehyde and phenol, which inhibit slime-formation and rancidity.

Salt is used for preserving vegetables. Using alternate layers of solid salt and vegetable, osmotic flow results in some dehydration of the vegetable and impregnation of the tissue with salt of maximum concentration (about 26 per cent). This inhibits bacterial growth, but on washing the salt out, a good deal of the flavour, Vitamins B_1 and C go out as well.

In lactic acid fermentation of vegetables such as cucumbers, cauliflower, and onions for pickles, salt of 10–12 per cent concentration is used to prevent the growth of spoilage bacteria, but this permits lactobacilli which ferment the sugars to lactic acid, helping in spoilage prevention of the pickled product.

It should be noted that nitrites can be toxic; they are liable to oxidise haemoglobin to methaemaglobin, which cannot transport oxygen; or to produce nitroso-haemoglobin, which is even worse. There is a report of babies in Norfolk[4] who died as a result of ingesting well-water containing 30 p.p.m. nitrate. The nitrate appears to have been reduced to nitrite by bacteria in the small intestine with fatal results, due to oxygen starvation.

TABLE V

The theoretical relationship between pH *and the inhibitory action of benzoic acid on growth of* Sacch. ellipsoideus *(after Ingram*[6]*, Rahn and Conn*[30]*)*

CONCENTRATIONS OF BENZOIC ACID IN MG/100 GM

*p*H	*Undissociated fraction (x)*	*Total acid*		*Undissociated acid*	
		Growth	*No growth*	*Growth*	*No growth*
3·5	0·83	21	42	18	35
3·65	0·77	17	30	13	24
4·1	0·55	34	42	19	23
4·4	0·38	42	85	16	31
5·0	0·13	212	420	28	55
5·7	0·027	212	420	6·7	11·5
5·8	0·022	850	1270	19	28
6·5	0·003		Over 2120		Over 6·4

Spices. Their value as preservatives has been over-rated. Their contribution is to flavour. Oil of clove and oil of cinnamon possess slight preservative value.

Mustard oil, otherwise Allyl Isothiocyanate, the essential principle of mustard, has some value in preventing spoilage[28], especially in acid products. Hence its usefulness in mustard pickle and salad cream. It has been used in preserving apple and grape juice.

Alcohol. This is of course, the main preservative in wines and spirits. As far as beer, ale, and stout are concerned, alcohol is one of several preservatives along with CO_2, pasteurisation, cold storage and good sealing. Commercial flavours are frequently dissolved in alcohol, which again aids in their preservation.

Group II.—Acid Preservatives

A large proportion of preservatives are acids, such as acetic, propionic, benzoic, dehydro-acetic, sorbic, sulphurous and boric acids. It will be noted that these are all weak acids.

The evidence (see especially Ingram, Ottaway and Coppock[1]; Ingram[6]; Rahn and Conn[30]) indicates that survival of micro-organisms is affected by three factors in particular:

(1) *p*H;

(2) concentration of undissociated acid;

(3) nature of the molecule.

A low *p*H:

(*a*) encourages yeasts and moulds at the expense of putrefactive and other bacteria;

(*b*) suppresses the enzymes of the latter and masks their noxious end products;

(*c*) lowers the heat resistance (Thermal death point) of many organisms (such as *Cl. botulinum*)—of great significance in canning, and other processes.

But acetic acid at a *p*H of 3 has a more powerful effect than hydrochloric acid at the same *p*H; and it has been shown by Rahn and Conn[30] that for any one preserving acid, e.g., benzoic acid, the concentration of the undissociated acid rather than the total acid, is the key factor required for inhibition of growth of a particular organism.

This is illustrated in the data shown in Table V. Here it is seen that growth at all *p*H's was prevented when the *undissociated* acid was about 25 mg. per 100 ml. while the *total* acid required to prevent growth had to be increased considerably at the higher *p*H's.

This helps us to understand why salicylic acid, because of its high dissociation constant, would be only useful in a highly acid food while for a neutral food, an acid of low dissociation constant such as dehydro-acetic acid, would be most effective.

Jacobs considers that the undissociated acid molecules, being uncharged, are better able to penetrate the cell barrier than charged ions.

But in addition, the direct chemical attack of the preservative plays a key part. Thus benzoic acid affects yeasts and moulds equally, whilst dehydro-acetic acid is especially effective against moulds, less so against yeasts, and still less against bacteria. Not enough is known about the mechanism of anti-microbial agents, but it is known that some preservatives affect Vitamin B group metabolism. Some suggestions have been made by Wyss[31] as to possible mechanisms. These are shown in Table VI.

TABLE VI (From Wyss[31])

POSSIBLE MODES OF ACTION OF SOME ACID PRESERVATIVES

Compound	*Activity*
Benzoic acid and derivatives	Membrane Action. Competition with co-enzymes.
Boric acid	Inhibition of phosphate enzymes.
Fatty acids	
long chain	Interference with cell membranes.
short chain	Competitive inhibition of enzymes.
Salicylic acid	Membrane action; competition with cozymase and with amino-acid metabolism.
SO_2 Derivatives ...	Inactivation of S-S-enzymes. Combination with intermediates in carbohydrate dissimilation.
Sorbic acid	Suppression of fumarate oxidation in catalase-positive organisms.

Part II

Consideration of Individual Acid Preservatives

Acetic Acid and Derivatives

THIS is the commonest of the acids used for preserving. It is usually used in the form of malt vinegar containing about 5 per cent acetic acid. This is used to preserve vegetables and fruit, in sauces and pickles, salad dressing, ketchups, etc.

In practice it has been found that for adequate protection the concentration should be at least 3·5 per cent based on the water phase. From the point of view of routine control, it is therefore necessary to determine the total solids, or to carry out the determination on the aqueous solution. It is important that this acid content should be equilibrated throughout the pack, if spoilage is to be avoided locally. If the acetic acid concentration is lower than this, as in a mild product like tomato ketchup, then it must be pasteurised. This figure can be lowered slightly for high sugar products, such as thick, sweet sauce, where there is a combined effect of osmotic action by the sugar and the action of the acetic acid.

Acetic acid is more effective against bacteria and yeasts than against moulds, and it may be used in bread in the form of vinegar to prevent rope formation (1 per cent of flour weight). The use of acetic acid is permitted, as it is regarded as a substance occurring naturally in foods. This is not the case with the associated substances discussed next.

Sodium Diacetate

$CH_3.COO\ Na.\ CH_3\ COO\ H.\ \frac{1}{2}H_2O$ and Calcium Diacetate $Ca(OOC.CH_3)_2\ CH_3COOH\ 6\ H_2O$ are both excellent rope and mould inhibitors[1], used in the U.S.A.[2,15]. These would not be permitted in this country, under the present regulations, but appear to be harmless[4].

Monochloracetic Acid has been banned in the U.S.A.[14,15] on account of its high toxicity, and is unlikely to be permitted here.

Dehydro-acetic Acid

(3-acetyl-6-methyl-1, pyran-2, 4[3] dione) can be regarded as a condensation product of acetic and aceto-acetic acids. This, too, has considerable anti-microbial properties[3], but its toxicity is said to be equal to that of phenol! A suitable use has been found for preserving rat bait containing warfarin.

Propionic Acid is permitted in some countries in the form of the acid, or its calcium and sodium salts as a mould and rope inhibitor in baked goods. For this purpose it is very effective, and is recommended for making canned bread in the U.S.A. to inhibit growth of *Cl.botulinum* during storage[5].

Propionates, which are non-toxic up to 3 per cent, are found naturally (1 per cent) in Swiss cheese. Propionic acid is oxidised in the body to pyruvic acid, which is a normal metabolite. Its use in baked goods in Britain has already been patented; and it seems to stand a good chance of being approved.

Sorbic Acid

$CH_3—CH=CH—CH=CH.COOH$ is effective against fungi and yeasts[6]. It is active against the moulds that grow on the surface of cheese; and its use might save considerable amounts of cheese as a result. There is special interest in its application to baked products[7]; as it has been shown that 0·1 per cent of sodium sorbate or sorbic acid in bread and cakes (based on flour weight) inhibit mould development very efficiently; thus sorbic acid is about four times as efficient as calcium propionate in high-ratio cakes. But sorbic acid inhibits yeast fermentation and sodium sorbate affects the flavour of bread undesirably. A solution to this difficulty has been reported by Elton[8], in the use of tissue paper impregnated with sorbic acid, inside a waxed paper for wrapping bread. This was supplied to the crew of the balloon "The Small World", which recently crossed the Atlantic. They found the bread perfectly edible and mould-free after four weeks.

Sorbic acid has passed searching toxicological tests, and appears to be metabolised in the body in the same way as its saturated analogue, caprioc acid[4], which is present in the glycerides of butter fat, palm kernel and coconut oils. It would appear to be suitable for use, and baking interests have pressed for its inclusion in future permitted preservatives, now under consideration. It should be noted that mould accounts for about 1 per cent loss of all bread[1], and that this cannot be avoided at the moment. Although it is not suitable for bread, sorbic acid is effective in cakes at about 0·2 per cent concentration, without affecting flavour.

Sulphurous Acid

This very widely used permitted preservative is usually applied in the form

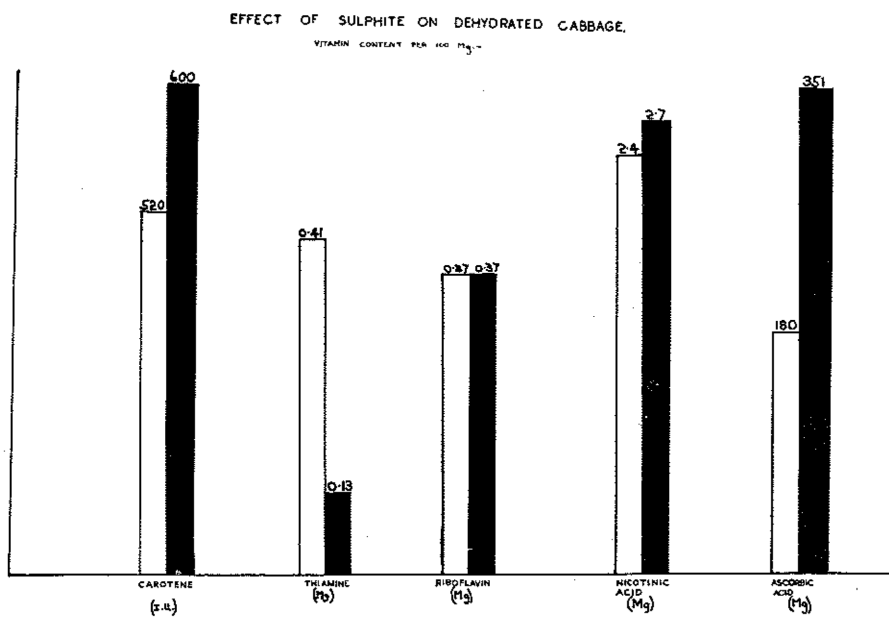

Fig. 1.—Hollow rectangles: no sulphite in blanching liquour
Solid rectangles: sulphite used in blanching liquour

Data from Pavcek[9]

of a 6 per cent solution of sulphur dioxide, although dried fruits, apple rings, etc., are treated with the gas directly. Sulphites are more successful against moulds than yeasts. Sulphur dioxide solution is used as one of the main preservatives for jam fruit pulps (up to 3,000 p.p.m.), liquid glucose, pectin solution, gelatine, sausage meat, and many other products. (See Table II, on Page 1.) It is often used as a dip or in the blanching liquor for vegetables for dehydration, and quick-freezing, as it protects ascorbic acid and carotene from destruction during the blanching process. This may be used in the form of sodium metabisulphite solution and is used repeatedly to conserve losses. Sulphurous acid helps to preserve the colour of fruit juice concentrates by decreasing the rate of the browning reaction, but Pavcek[9,28] has reported that sulphites destroy thiamine in foods. This is illustrated in Fig. 1.

A good deal of the SO_2, however, is lost because of its reaction with aldehydes and other food constituents, especially glucose[6]. The sulphonic acid so formed has no preserving function. Of the remainder, only the undissociated H_2SO_3 is effective. It has been shown by Vas and Ingram[10] that addition of 270 mg./litre of SO_2 to a 65° Brix orange juice gave only 65 mg./litre free sulphur dioxide, of which only 1·5 mg./litre consisted of *active* H_2SO_3. But the large amount permitted makes up for this. Fortunately, the effects of long exposure and rapid boiling result in the loss of any uncombined SO_2 in the product when consumed. The remaining combined SO_2 (up to 100 p.p.m. is permitted in jam) has no preservative function and probably no toxic effect, but this is not taken account of in the prescribed limits.

Benzoic Acid

This is the other major permitted preservative. (See Table III, on Page 2.) It is not used so widely as SO_2. It may be used in the form of the free acid, or its salt, but as it is used widely in acid fruits, the free acid is usually liberated as the main agent. It is used for fruit juices, coffee extracts and soft drinks of all kinds. It is primarily anti-microbial, and there are some yeasts which can grow in the maximum allowed concentration of 600 p.p.m. This was shown in the hot summer of 1956 when many reports of fermentation in orange and lemon squashes were received[6]. The *p*H in some cases was down to 2·5.

Benzoic acid and its salts are flavourless and being non-volatile the consumer gets the whole of it. But it is very safe, because it is completely excreted in the urine in the form of benzoyl-glycine (hippuric acid) in a very short space of time. Even as much as 4 g. a day consumed over a long period, produced, according to Sollmann[11], no ill effects in humans.

Esters of benzoic acid, which are not, at present, permitted, are more effective than benzoic acid, as the undissociated portion is in greater concentration. They are hydrolysed by esterases, which are plentiful in the gut and liver, and are therefore as safe as benzoates.

Substituted Benzoates—p-Chlorobenzoic acid is an effective preservative, and is permitted in Germany. p-Hydroxy benzoic acid is a better preservative than benzoic[1,6], especially if esterified; Hans Von Schelhorn[12] showed that at *p*H 6·6, 4 per cent of sodium benzoate was needed to prevent growth of *B.coli*, whereas only 0·1 per cent of ethyl p-hydroxy benzoic acid was required to achieve the same effect.

The toxicities and metabolism in the body of these substances are about the same. Hence, there are distinct possibilities here. Vanillic acid, a methoxy derivative of p-hydroxy benzoic acid is also of interest in having good preservative effect.

Ethyl and n-butyl esters of p-hydroxy benzoic acid have about the same toxicity as benzoic acid, and 0·1 per cent can be incorporated into bread, with mould reducing properties, and no unpleasant effects.

But o-hydroxy benzoates, although good preservatives, are not metabolised in the body and must be rejected.

Boric Acid and Borates

At one time cream, butter, margarine, meats and even milk were preserved with these compounds. It is only six years since boric acid was forbidden. Until then it was allowed in margarine (2,500 p.p.m.) as an emergency measure. It has been shown to be toxic—it is only slowly excreted, and accumulates in the body, causing dyspepsia and other unpleasant symptoms.

Group III.—Antibiotics

The list and discussion of preservatives would not be complete without reference to a whole new class which has entered the field in recent years. These are the antibiotics, which might be taken to refer to substances which have been made by microbiological action, and subsequently separated from the culture medium.

In view of their powerful antibacterial uses in medicine it is not surprising that their use has been extended to the field of food technology[13,16,17,18,19,25].

A great deal of discussion has taken place regarding the wisdom of using antibiotics which are also used for medical purposes. Not enough is known about the effect of small amounts of antibiotic taken over a period of time, on the natural flora of the alimentary canal. Further it could conceivably affect the efficacy of the same antibiotic when used to counteract a pathogenic organism which had developed immunity to that particular antibiotic. This situation may possibly become more complicated as a result of the dosing of poultry with antibiotics to produce bigger and better birds, and the treatment of pigs for greater carcass weight. So far no evidence has been received to indicate that immunity has been conferred upon any bacteria as a result. The question of allergy has been raised, but again there are no known cases of people who have become allergic to the presence of antibiotics in foods.

Antibiotics used in Medicine

Chlorotetracycline (CTC) or *Aureomycin*, *Oxytetracycline* (OTC) or *Terramycin*, and *Chloramphenicol* are examples of antibiotics that have been applied to fresh foods in various ways.[16,20,23]

Feeding the animals before being killed results in residues of the antibiotic being retained in the food, and results in a longer shelf life for meat and poultry.

Chlorotetracycline has been used to preserve carcasses of poultry, pigs and cattle by spraying, dipping, and by injection.

On the whole, results have been very promising, but the action of yeasts appears not to be discriminated against; and one effect is the development of hydrolytic rancidity owing to lipase activity. This would suggest that it is less suitable for fatty than for lean tissue.

Aureomycin has been used successfully for minced meat, for sausages and for sausage skins, leading in each case to the extension of shelf life.

An excellent application in fish preservation has been the use of chlorotetracycline ice (Shewan and Stewart)[22]. Work at Torry Research Station has shown that the use of ice containing 3–5 p.p.m. CTC for packing freshly caught fish extended the storage life from 13 to 23 days. Noticeable in the treated fish was the

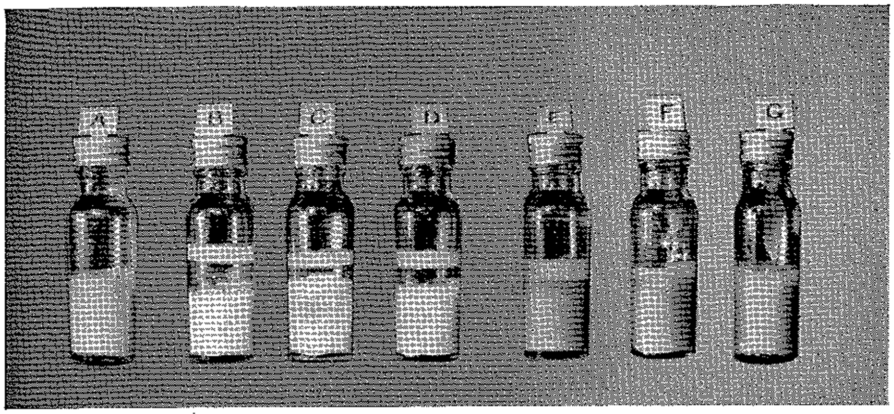

Fig. 2.—The effect of nisin on litmus milk inoculated with Clostridium butyricum
A. No organism. No Nisin.
B. Inoculated. Nisin content 0.25 Reading Units per ml.
C. ,, ,, ,, 2.5 ,, ,, ,, ,,
D. ,, ,, ,, 25 ,, ,, ,, ,,
E. ,, ,, ,, 100 ,, ,, ,, ,,
F. ,, ,, ,, 200 ,, ,, ,, ,,
G. ,, ,, ,, 250 ,, ,, ,, ,,
Note the gas production in tubes B, C and D

absence of slime and ammoniacal odour. There was little penetration into the deeper-seated tissues and after cooking by various means, there was no adverse effect on flavour, and CTC was virtually absent in the flesh.

Similar good results have been obtained with CTC ice used for poultry. For "red meats" experimental methods have included intra-arterial or intra-peritoneal injection prior to slaughter; and the killing of whales by using missiles with an explosive "head" containing antibiotics.

The tetracyclines have given the most promising results in food preservation, because of their widespread effect among different bacterial groups, Gram-positive as well as Gram-negative.

The Food and Drug Administration of U.S.A in 1955 allowed the use of the above CTC ice treatment for raw poultry in approved plants[16]. Cleaned eviscerated birds are added to a tank one-third full of water containing 10–30 p.p.m. of CTC to bring the level up to two-thirds of the tank. The remaining third of the tank is filled with ordinary ice. The contents are vigorously agitated by air hoses for one half to two hours. The tolerance in the raw birds is 7 p.p.m. in any portion, and it has been established that after cooking no significant residue is left in the bird. In Canada, CTC and OTC are permitted to be used for fish and poultry, the tolerance for raw fish being 5 p.p.m.

No West European country, including Britain permits their use at the moment.

Other Antibiotics

As indicated earlier, there is some criticism of the use of antibiotics for food preservation, which are already in use in the medicinal field[17]. No such objections, however, can be sustained against the use of the two antibiotics discussed next, subtilin and nisin, which have no medicinal uses.

Subtilin is an antibiotic obtained from *Bacillus subtilis.* In 1950 Anderson and Michener[13,32] showed that 5 p.p.m. of subtilin and 10 minutes heating in boiling water; or 10 p.p.m. subtilin and 5 minutes heating were enough to preserve canned peas satisfactorily.

This is confirmed in canning practice by Campbell *et al*[21], who report that subtilin reduces the processing times required for certain thermophilic and mesophilic organisms. The authors stress that where there is any danger of infection by *Cl.botulinum,* subtilin (and nisin) are inadequate for complete protection, and thorough heat sterilisation is then essential.

This would be a tremendous boon to the canning industry, especially at time of glut, as there could be a vast increase in the amount of food processed as a result of the time saved, for example during the highly concentrated pea season.

Nisin is in a class by itself, as it is the only antibiotic so far known that is already being produced in considerable quantities in a food process[23, 24, 25, 26]. It is produced by some strains of *Streptococcus lactis* (occurring naturally in milk), which is used as a starter in cheese and margarine manufacture. It is a protein of low molecular weight and is completely non-toxic (or we should have to stop eating cheese). It is effective against various strains of food spoilage organisms notably Clostridia, Streptococci, and Staphylococci.

Uses:

It can be used in ice in the same way as CTC, as has been shown at Torry Research Station[22]. It also prevents Clostridia attack on low acid cheeses, such as continental types: Parmesan, Gouda and Edam.

Nisin is particularly useful in the manufacture of processed cheese. It eliminates the spoilage of these cheeses by many Clostridia types, which lead to gas holes and blowing, deterioration of flavour, and even putrefaction.

Experiments have shown (Lilley[24]) that nisin added at the rate of 100 Reading Units per gram prevented after 6 months any spoilage in cheese *inoculated* with Clostridia; whereas a small packet of processed cheese treated in the same way, but containing no nisin, showed after the same period considerable distension and "blowing". (See Figs. 3 and 4.)

As a result of the consistent use of nisin, the losses of one British manufacturer are said to have been practically eliminated since 1955.

Nisin has been used successfully in food processing in the same way as the use of subtilin. Nisin lowers the heat resistance of many thermophilic organisms, and so cuts down the time and temperature required to destroy them. Hawley[24] claims that nisin will control

Fig. 3.—Portions of processed cheese after six months storage at room temperature. (Left) No nisin added, gas produced by Clostridia causing distension; (Right) containing 100 units of nisin per gram of cheese
By courtesy of "Research" (M. D. Lilley[26]).

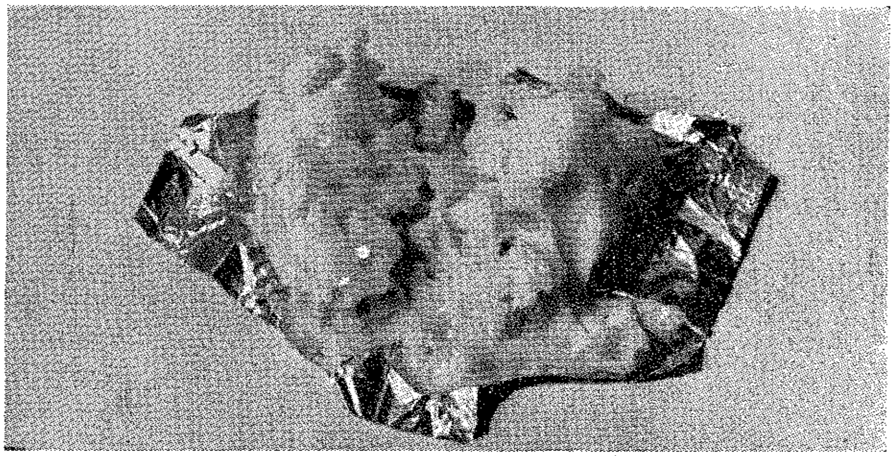

Fig. 4.—Spoiled cheese opened to show Clostridial "blowing"
By courtesy of "Research" (M. D. Lilley[26]*).*

both flat souring and hard swells of canned vegetables. This should find wide application; and has been shown to be of great assistance in canning tomato products.

In the canning of peas, the commonest spoilage organisms are the "flat sour" organisms, facultative thermophilic anaerobes such as *B.stearothermophilus*, and in addition, "hard swells", caused by organisms such as *Cl.thermosaccharolyticum.* Work carried out at the Fruit and Vegetable Canning and Quick-Freezing Research Station has demonstrated that nisin can satisfactorily control these organisms in pea canning. Similar, but not quite such spectacular results have been achieved with beans in tomato sauce.

The protective mantle of nisin would particularly shield packs which travel to warmer countries, and would also lessen the dangers due to insufficient cooling of cans stacked after retorting. But it must be emphasised that nisin or any other antibiotic must never be allowed to be used as a substitute for poor processing, or bad hygiene.

Nisin is now being made commercially available by at least one dairy firm. Nisin occurs naturally in the alimentary tracts of cows and humans. It is digested very easily by the proteolytic enzymes in the gut.

The level of use in experiments have been of the order of 2–4 μg/g. for processed cheese, and 1–5 μg/g. for canned peas. Nisin is also active against many species of Staphylococci and Streptococci. It should be noted that Staphylococci have been repeatedly incriminated as causes of food poisoning. In 1955 there were 138 *reported* cases. Staphylococci are often spread by septic fingers, or by nasal contact on foods such as open pack cooked meats, pies, etc., in canteens and kitchens. The use of nisin might reduce the danger from these organisms.

It is of special interest in that, although antibiotics are not at present permitted in foods, nisin appears to be in a special category; and it remains to be seen whether its use would be regarded as a breach of the Preservatives in Food Regulations as they now stand.

Summing Up

To a manufacturer, the problem of applying preservatives is a difficult one, as he must consider the cost, the effect on appearance and flavour, above all its usefulness in doing the job claimed for it, and the question of health hazards to his employees as well as the consumers.

The impetus is the large wastage of food which takes place in every country, in every part of the food industry. To mention a few: mould and rope in bread and cakes, mould on cheese, the wasted surplus of fruit and vegetables at harvest time. The judicious use of safe preservatives could result in economies in the costs of food processing, and most important, a reduction in food poisoning. The greater accessibility of food to populations which need it, whether for economic or geographical reasons, or by reason of seasonal non-availability, are also factors justifying the search for, development and application of new methods of preservation. They can hardly fail to be of benefit to mankind.

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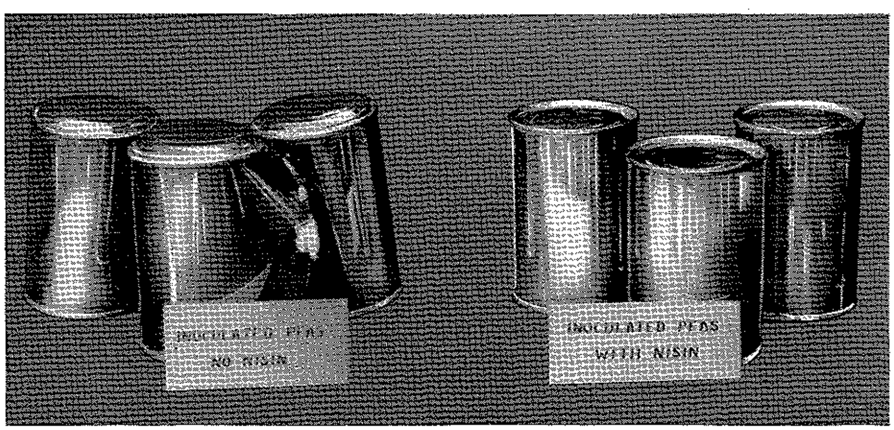

Fig. 5.—Peas canned and inoculated with Clostridium butyricum *showing blown and burst cans without nisin; and the prevention of these effects when nisin was added*

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