Consortium for Educational Communication

Module

on

Chemical Methods Of Food Preservation

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TEXT

Introduction

Food is indispensable for humans. The supply of food and other essentials continues to have a huge impact on the development of human society as a whole. Increasing world population not only causes an increase in the food demand and supply but also makes the minimization of food wastage due to spoilage imperative. While food production is a significant part of the process to ensure constant, varied, harmless, food supplies to cater to the consumer demands, food preservation becomes important to achieve the balance between the supply and demand of food.

This loss of quality of foods depends on a number of factors which includes the type of food, its chemical composition, the type of packaging employed and the storage conditions the foods were subjected to. All the food items have a tendency to be spoiled at any of the phases ranging from acquirement of raw materials to the consumption of food. This tendency of spoilage can be augmented or lessened at any of these stages. This makes the complete preservation of foods a multi-factor process as it depends on more than one component and requires regulation at more than one of those components to achieve the required results.

Food Preservation

Food preservation is an action or method of designed to maintain foods at a desired level of quality. A number of new preservation techniques are being developed to satisfy current demands of economic preservation and consumer satisfaction in safety, nutritional and sensory aspects.

The strategy for the preservation of foods requires the implementation of some steps whereby food stuffs undergo some processing. Preservation techniques are numerous and generally differ from one food product or food class to another. In practice, a combination of techniques is sometimes preferred in order to achieve the desired preservation without tampering with safety or the integrity of the food product.

Basis of Food Preservation

Preservation is based predominantly on delaying or preventing the growth of microorganisms. It, therefore, must operate through those factors that most effectively influence microbial growth and survival. These include a number of physical and chemical factors, and also microbiological factors, which depend on the nature of the microorganisms that are present. The factors have been classified in a number of ways, but the most widely quoted categorization separates the major factors into the following:

i. *Intrinsic Factors*. These include chemical and physical factors that are normally within the structure of the food, and with which a contaminating microorganism is therefore inextricably in contact.

ii. *Processing Factors*. These, as the name implies, are deliberately applied to foods in order to achieve improved preservation.

iii. *Extrinsic Factors*. These include those factors that influence microorganisms in foods but which are applied from outside the food and act during storage.

iv. *Implicit Factors*. These include those factors that are related to the nature of the microorganisms themselves, and to the interactions between them and with the environment with which they are in contact during growth.

v. *Net effects*. These take into account the fact that many of the factors strongly influence the effects of each other, so that the overall effect of combinations of factors may not be readily predictable but may usefully act synergistically to give greater effects than

one would expect from the single factors. These form the basis of so-called "combination preservation".

Need of Preservation

The idea of food preservation arises from the desire to maintain the food quality, its physico-chemical properties and maintain the functionality of its nutritious components without affecting the product itself.

The main reasons for food preservation are to overcome inappropriate planning in agriculture, produce value-added products, and provide variation in diet. Throughout civilisation, there has always been a need to preserve food for future use for a number of reasons.

These include:

- to maintain the integrity of food products;

- for increasing the shelf-life of food products;
- for replenishment of food supply during famine (food security);
- transporting of food products for use in a different locality;
- providing value-added food products that can give better-quality foods in terms of improved nutritional, functional, convenience, and sensory properties;
- meeting the consumer demand for healthier and more convenient foods;
- allowing for variation in the diet, particularly in underdeveloped countries to reduce reliance on a specific type of grain (i.e., rice or wheat)

Food Preservation Methods

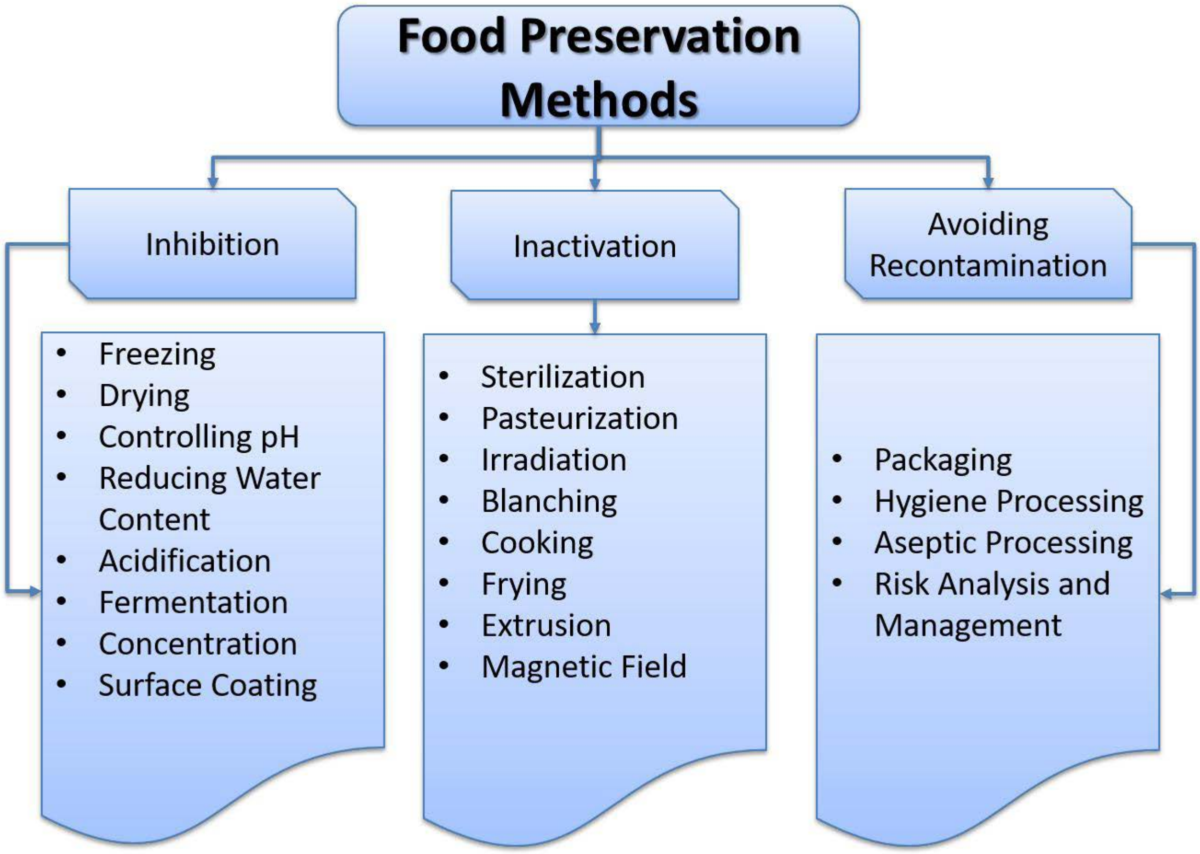
The preservation and processing of food is not as simple or straightforward as it was in the past: it is now progressing from an art to a highly interdisciplinary science. A number of new preservation techniques are being developed to satisfy the current demands of economic preservation and consumer satisfaction and environmental safety. The preservation methods are mainly based on the types of food that need to be prepared or formulated. The factors that are considered before selecting a preservation process include the desired quality of the product, the economics of the process, and the environmental impact of the methods.

At present different methods of food preservation are available for the food industry. Based on the mode of action, the major food preservation techniques can be categorized as

(i) slowing down or inhibiting chemical deterioration and microbial growth,

(ii) directly inactivating bacteria, yeasts, moulds, or enzymes, and

(iii) avoiding recontamination before and after processing.



Modern preservation methods are designed not only to extend the shelf life of food, but also to ensure its safety by inactivating pathogenic microorganisms and viruses of concern, or in some cases just preventing their growth in the product.

Food Preservation with Chemicals

The use of chemicals to prevent or delay the spoilage of foods derives in part from the fact that such compounds are used with great success in the treatment of diseases of humans, animals, and plants. Although a large number of chemicals have been described that show potential as food preservatives, only a relatively small number are allowed in food products, due in large part to the strict rules of safety adhered to by the Food and Drug Administration (FDA) and to a lesser extent to the fact that not all compounds that show antimicrobial activity in vitro do so when added to certain foods.

Following are the chemical preservatives *generally recognized as safe* (GRAS):

Preservatives	Tolerance	Organisms Affected	Foods
Propionic acid	0.32%	Moulds	Bread, cakes, some cheeses, rope inhibitor in bread dough
Sorbic acid	0.2%	Moulds	Hard cheeses, figs, syrups, salad dressings, jellies, cakes
Benzoic acid	0.1%	Yeasts and Moulds	Margarine, pickle relishes, apple cider, soft drinks, tomato catsup, salad dressings
Parabens	0.1%	Yeasts and Moulds	Bakery products, soft drinks, pickles, salad dressings
SO_2/sulfites	200-300 ppm	Insects and Microorganisms	Molasses, dried fruits, wine making, lemon juice
Ethylene/ Propylene Oxides	700ppm	Yeasts, Moulds, Vermin	Fumigant for spices, nuts
Sodium diacetate	0.32%	Moulds	Bread
Nisin	1%	Lactics, clostridia	Certain pasteurized cheese spreads
Dehydroacetic acid	65ppm	Insects	Pesticide on strawberries, squash
Caprylic acid	-	Moulds	Cheese Wraps
Ethyl formate	15-220 ppm	Yeasts and Moulds	Dried fruits, nuts

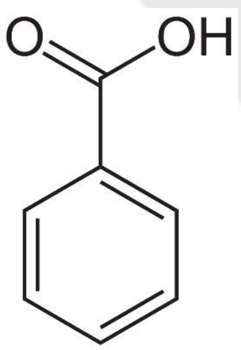
Below are described those compounds most widely used, their modes of action where known,

and the types of foods in which they are used:

1. BENZOIC ACID

Sodium benzoate was the first chemical preservative permitted in foods by the FDA, and it continues in wide use today in a large number of foods. Its common approved derivatives are Methylparaben Methyl p-Hydroxybenzoate, Propylparaben Propyl p-Hydroxybenzoate, Heptylparaben n-Heptyl-p-Hydroxybenzoate

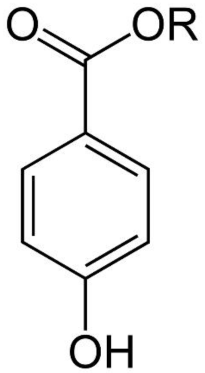
It has been found that benzoic acid blocks the oxidation of glucose and pyruvate at the acetate level. The antimicrobial activity of benzoate resides in the undissociated molecule and is related to the pH. The undissociated form is essential to the antimicrobial activity of benzoate. In this state, these compounds are soluble in the cell membrane and act apparently as proton ionophores. As such, they facilitate proton leakage into cells and thereby increase energy output of cells to maintain their usual internal pH. The pK of benzoate is 4.20 and at a pH of 4.00, 60% of the compound is undissociated, whereas at a pH of 6.0, only 1.5% is undissociated. This results in the



restriction of high-acid products such as apple cider, soft drinks, tomato ketchup, and salad dressings by benzoic acid and its sodium salts. High acidity alone is generally sufficient to prevent growth of bacteria in these foods but not that of certain moulds and yeasts. As used in acidic foods, benzoate acts essentially as a mould and yeast inhibitor. Against yeasts and moulds at around pH 5.0-6.0, from 100 to 500 ppm are effective in inhibiting the former, whereas for the latter, from 30 to 300 ppm are inhibitory.

2. PARABENS

The common parabens that are permissible in foods are heptyl-, methyl-, and propyl-, butyl- and ethylparabens. In general, gram-positive bacteria are more susceptible than gram negatives to the parabens. The parabens appear to be more effective against moulds than against yeasts.

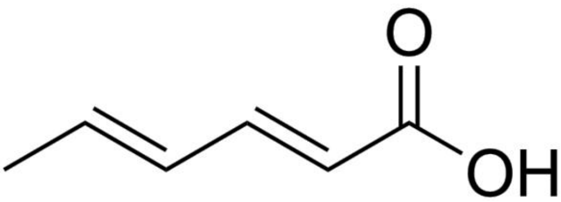


As esters of *p*-hydroxybenzoic acid, they differ from benzoate in their antimicrobial activity in being less sensitive to pH. The pK for these compounds is around 8.47, and their antimicrobial activity is not increased to the same degree as for benzoate with the lowering of pH as noted. They have been reported to be effective at pH values up to 8.0.

Heptylparaben is quite effective against microorganisms at a concentration of 10-100 ppm affecting complete inhibition of some gram-positive and gram-negative bacteria. It is also effective against the malo-lactic bacteria. *Propylparaben* is more effective than *methylparaben*, with up to 1,000 ppm of the former and 1,000-4,000 ppm of the latter needed for bacterial inhibition.

3. SORBIC ACID

Sorbic acid (CH3CH—CHCH—CHCOOH) is employed as a food preservative, usually as the calcium, sodium, or potassium salt. Sorbate inhibits microbial cells by the general mechanism involving the proton motive force (PMF). It causes weakening of the transmembrane gradient such that amino acid transport is affected adversely.



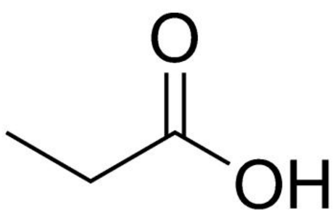
Like sodium benzoate, they are more effective in acid foods than in neutral foods and tend to be on par with the benzoates as fungal inhibitors. Sorbic acid works best below a pH of 6.0 and is generally ineffective above pH 6.5. These compounds are more effective than sodium benzoate between pH 4.0 and 6.0. At pH values of 3.0 and below, the sorbates are slightly more effective than the propionates but about the same as sodium benzoate. The pK of sorbate is 4.80, and at a pH of 4.0, 86% of the compound is undissociated, whereas at a pH of 6.0, only 6% is undissociated.

The sorbates are primarily effective against moulds and yeasts, but research has shown them to be effective against a wide range of bacteria. Shelf-life extensions have been obtained by use of sorbates on fresh poultry meat, vacuum-packaged poultry products, fresh fish, and perishable fruits. The sorbates have been studied by a large number of groups for use in meat products in combination with nitrites. The combination of sorbate plus reduced nitrite has been shown to be effective in a variety of cured meat products against not only *C. botulinum* but other bacteria such as *S. aureus* and a spoilage *Clostridium* (putrefactive anaerobe [PA.] 3676) where a noninhibitory concentration of nitrite and sorbate was bactericidal.

The widest use of sorbates is as fungistats in products such as cheeses, bakery products, fruit juices, beverages, salad dressings, and the like. In the case of moulds, inhibition may be due to inhibition of the dehydrogenase enzyme system. Against germinating endospores, sorbate prevents the outgrowth of vegetative cells.

4. THE PROPIONATES

Propionic acid is a three-carbon organic acid with the structure CH3CH2COOH.



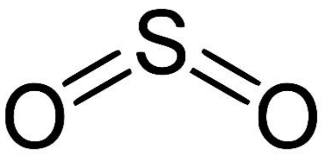
This acid and its calcium and sodium salts are permitted in breads, cakes, certain cheese, and other foods, primarily as a mould inhibitor. The tendency of propionic acid and its salts towards dissociation is low, and they are consequently active in low-acid foods. They tend to be highly specific against moulds, with the inhibitory action being primarily fungistatic rather than fungicidal.

With respect to the antimicrobial mode of action of propionates, they act in a manner similar to that of benzoate and sorbate. The pK of propionate is 4.87 and at a pH of 4.00, 88% of the compound is undissociated, whereas at a pH of 6.0, only 6.7% remains undissociated. The undissociated molecule of this lipophilic acid is necessary for its antimicrobial activity. The mode of action of propionic acid is similar to that of benzoic acid.

5. SULFUR DIOXIDE

Sulfur dioxide (SO2) and the sodium and potassium salts of sulfite (=S03), bisulfite (—HSO3), and metabisulfite (=S2O5) all appear to act similarly.

Sulfur dioxide has been used as a food preservative since ancient times. Its use as a meat preservative dates back to at least 1813. It is used in its gaseous or liquid form on dried fruits, in lemon juice, molasses, wines, fruit juices, and others.



Sulfur Dioxide is bacteriostatic (at low pH and concentrations of 100-200 ppm) as well as bactericidal (at concentrations >200ppm). Moulds can be controlled on grapes by periodic gassing with SO2, and *bisulphite* can be used to destroy aflatoxins.

Although the actual mechanism of action of SO2 is not known, several possibilities have been suggested. It has been proposed that the undissociated sulphurous acid or molecular SO2 is responsible for the antimicrobial activity. Its greater effectiveness at low pH tends to support this argument. SO2 is also thought to be an enzyme poison, inhibiting growth of microorganisms by inhibiting essential enzymes. Because the sulphites are known to act on disulphide bonds, it may be presumed that certain essential enzymes are affected and that inhibition ensues. Its use in the drying of foods to inhibit enzymatic browning is based on this assumption.

6. NaCl AND SUGARS

These compounds are grouped together because of the similarity in their modes of action in preserving foods. NaCl has been employed as a food preservative since ancient times. The inhibitory effects of salt are not dependent on pH, as are some other chemical preservatives.

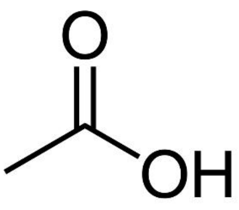
The early food uses of salt were for the purpose of preserving meats. This use is based on the fact that at high concentrations, salt exerts a drying effect on both food and microorganisms. When high concentrations of salt are added to fresh meats for the purpose of preservation, both the microbial cells and those of the meat undergo plasmolysis (shrinkage), resulting in the drying of the meat, as well as inhibition or death of microbial cells. Enough salt must be used to affect hypertonic conditions. The higher the concentration of the sale, the greater is the preservative and drying effect.

Sugars, such as sucrose, exert their preserving effect in essentially the same manner as salt. Higher concentrations of sugars make water unavailable to microorganisms. One of the main differences is in relative concentrations. It generally requires about six times more sucrose than NaCl to effect the same degree of inhibition. The most common uses of sugars as preserving agents are in the making of fruit preserves, candies, condensed milk, etc. Microorganisms differ in their response to hypertonic concentrations of sugars, with yeasts and moulds being less susceptible than bacteria. Some yeasts and moulds can grow in the presence of as much as 60% sucrose, whereas most bacteria are inhibited by much lower levels.

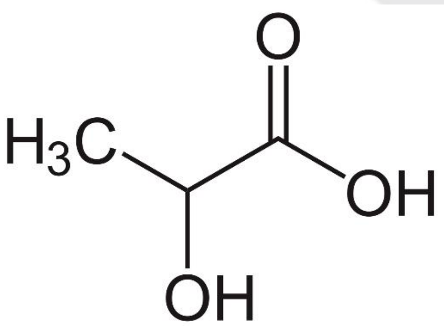
7. ORGANIC ACIDS

The antimicrobial effects of organic acids are due to both the depression of pH below the growth range and metabolic inhibition by the undissociated acid molecules. Organic acids are employed to wash and sanitize animal carcasses after slaughter to reduce their carriage of pathogens and to increase product shelf life

Acetic acid and lactic acid are among the most widely employed organic acids as preservatives.



Acetic Acid



Lactic Acid

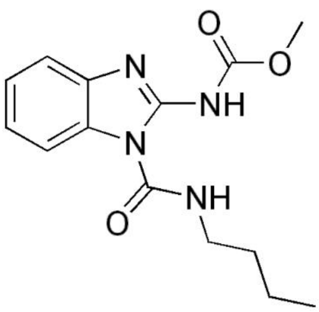
In most instances, their presence in the subject foods is due to their production within the food by lactic acid bacteria. Products such as pickles, sauerkraut, and fermented milks, among others, are created by the fermentative activities by various lactic acid bacteria, which produce acetic, lactic, and other acids. The bactericidal effect of acetic acid can be demonstrated by its action on certain pathogens which when exposed to 10% acetic acid were undetectable after 10 minutes.

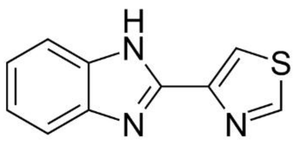
8. ANTI-FUNGAL AGENTS FOR FRUITS

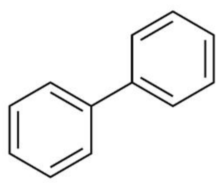
A number of chemical agents employed to control fungal spoilage of fresh fruits. Following table enlists some of those compounds:

Compound	Fruits
Thiabendazole	Apples, pears, citrus fruits, pineapples
Benomyl	Apples, pears, bananas, citrus fruits, mangoes, papayas, peaches, cherries, pineapples
Biphenyl	Citrus Fruits
SO_2 Fumigation	Grapes
Sodium-α-phenylphenate	Apples, pears, citrus fruits, pineapples

Benomyl is applied uniformly over the entire surface of fruits. It can penetrate the surface of some vegetables and is used worldwide to control crown rot and anthracnose of bananas, and stem-end rots of citrus fruits.







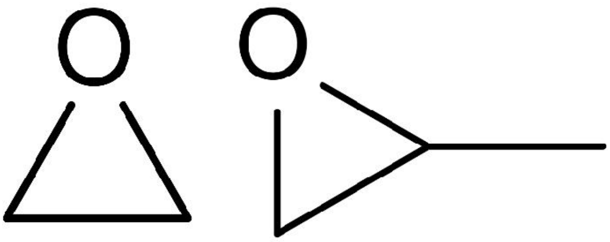
Benomyl Thiabendazole Biphenyl

Both benomyl and *thiabendazole* are effective in controlling dry rot caused by

Fusarium spp. To prevent the spread of *Botrytis* from grape to grape, *sulphur dioxide* is employed for long-term storage. It is applied shortly after harvest and about once a week thereafter.

9. ETHYLENE AND PROPYLENE OXIDES

The ethylene and propylene oxides exist as gases and are employed as fumigants in the food industry. The oxides have a similar mechanism of action are applied to dried fruits, nuts, and spices primarily as antifungal compounds.



Ethylene Oxide **Propylene Oxide**

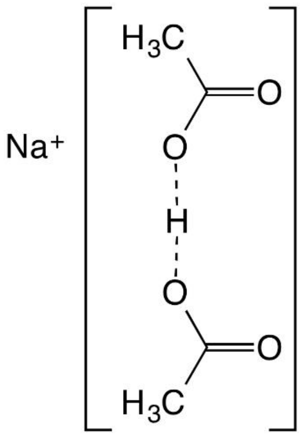
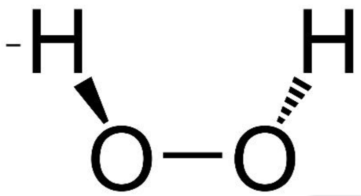
Ethylene oxide is an alkylating agent. Ethylene oxide appears to affect endospores by alkylation of guanine and adenine components of spore DNA. It is also used as a gaseous sterilant for flexible and semirigid containers for packaging aseptically processed foods.

10. OTHER CHEMICAL PRESERVATIVES

a. Sodium diacetate, a derivative of acetic acid, is used in bread and cakes to prevent mouldiness. Organic acids, such as citric acid, exert a preserving effect on foods such as soft drinks.

b. Hydrogen peroxide (H2O2) has received limited use as a food preservative. In combination with heat, it has been used in milk

pasteurization and sugar processing, but its widest use is as a sterilant for food-contact surfaces of olefin polymers and polyethylene in aseptic packaging systems.

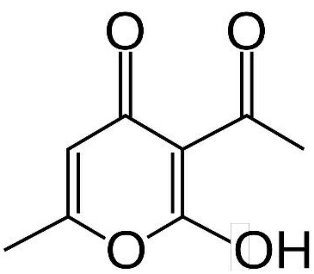
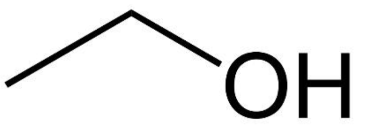



c. Ethanol (C2H5OH) is present in flavoring extracts and effects preservation by virtue of its desiccant and denaturant properties.

Ethanol vapours, produced by a vapour generator, can be produced within the headspace of a package, and the vapours have

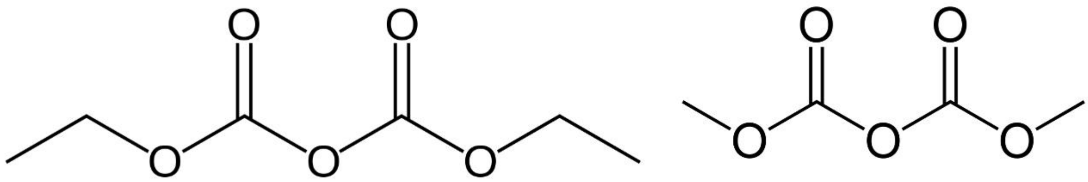
been shown to be effective against some bacteria and fungi.

d. Dehydroacetic acid is used to preserve squash.

e. Diethylpyrocarbonate has been used in bottled wines and soft drinks as a yeast inhibitor. It decomposes to form ethanol and CO2 by either hydrolysis or alcoholysis.
Sometimes urethane is formed when this compound is used, and because it is a carcinogen, the use of diethylpyrocarbonate is no longer permissible

f. Dimethyl dicarbonate (DMDC) is used as a yeast inhibitor in wine and some fruit drinks at a level of 0.025%. Upon hydrolysis, it yields methanol and CO2.



DMDC has been found to be more effective than sodium bisulphite and sodium

benzoate as an inhibitor of *E. coli* 0157:H7