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# Role of chemistry in modern world: Boons and banes of chemical coating effects on human health

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## Abstract

Water is the principal component of fresh fruits and Vegetable which constitutes between 80 to 90% of a produce's fresh weight. Fruits are covered by a layer of natural wax which acts as a barrier to reduce moisture loss and at the same times give the fruit a shiny surface. Besides orange shellac, other common materials used for these purposes include starch, carrageenan, alginates, wood rosin and various waxes. Panko breadcrumbs are crucial to the vegetables being very crispy. The coatings are typically made from natural materials, such as CHI, cellulose, and pectin that are safe for human consumption. The multilayer coating method has been shown to be effective in extending the shelf life of a variety of fresh fruits and vegetables, including apples, strawberries, tomatoes, and cucumbers. Both natural waxes (carnauba, shellac, beeswax or resin) and petroleum-based waxes (usually proprietary formulae) are used, and often more than one wax is combined to create the desired properties for the fruit or vegetable being treated. However, chemical treatments, such as copper sulfate, rhodamine oxide, malachite green, and deadly carbide, used on green vegetables to enhance coloration and freshness, are often counterproductive to their nutritional value. There is multiple health risks associated with these chemicals. This study reveals that food preservatives have made a big difference in eating food every day. They help keep the food safe because they add these chemicals to prevent spoilage and retard prevent or control undesirable changes in flavor, color, texture, or consistency of food and nutritive value of food which means the Control natural spoilage of food.

**Keywords:** Fruits; Vegetables; Coatings; Human consumption; Chemical treatments; Multiple health risks

## 1 Introduction

In the modern food industry, food preservation plays a vital role in ensuring that food products reach consumers in a safe and desirable condition. Chemical food preservation methods have significantly contributed to addressing challenges associated with food spoilage, transportation, and storage. By utilizing preservatives, the industry can reduce food waste, extend product availability, and maintain nutritional value and sensory characteristics [1]. Ages-old the food was preserved by the following methods – Cooling, freezing and fermentation etc. One of the most frequently used methods for food preservation is sun-drying. This is very helpful because if the water has evaporated and the remaining water is insufficient then micro-organisms cannot be augmented. Secondly, cooling can also be used for food preservation as cooling can decrease the rate of chemical reaction and can also slow down the growth of microorganisms. Salt is one of the most useful preservatives for food and for keeping the pickles fresh because

- It extracts excess water from the fruits.
- Maintains the flavour of the fruit.
- Maintains the texture of the fruit.

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Oil is used in pickles as it locks the air from the item that is being pickled. Jams/Jellies last for a longer time as compared to cakes or other sweets because Jams/Jellies contain more sugar as compared to cakes and other sweets. Through osmosis, sugar extracts the water from the fruit which helps in the preservation of food [3-5].

Preservation techniques have been used as far back as the 14th century when man first used salt (salting) and smoke (curing) to stop meat and fish from going bad. Nowadays, the use of food additive preservatives has become an indispensable part of the food we eat. Despite a number of misgivings about their safety, our increasing demand for greater choice, ease and convenience of foods, and our high standard of food safety, makes them a vital component in our food systems. Let's explore the varying ways preservatives keep our foods fresh, safe, and shelf stable [5-6].

Increasing demands of consumers for high quality fresh food products have increased the interest in the development of new food processing technologies over the past decade. Food preservation is processing designed to protect food from spoilage caused by microbes, enzymes, and auto-oxidation. It is one of the oldest technologies used by human beings to prevent from food-borne disease hazards. The basic idea behind food preservation is either to slow down the activity of disease-causing bacteria or to kill the bacteria altogether [7]. Nowadays different preservation techniques commonly used worldwide like Refrigeration and freezing, Canning, Dehydration, Freeze-drying, Salting, Pickling, Pasteurizing, Fermentation, Carbonation, Cheese-making and Chemical preservation [8-10].

Nowadays, fruits and vegetables are highly demanded in the market because of its nutritional value. Due to their perishable nature, fruits and vegetables have a short shelf life. About 30% fruits and vegetables are affected or damaged by insects, microorganisms, pre and post harvesting conditions during transport and preservation [11]. Preservation of fruits and vegetables is a big challenge for world. Edible coating is an effective method to solve this problem. It provides protective edible covering to fruits and vegetables. It is beneficial for consumers and environment. Today herbal edible coatings are used as a nutraceuticals and beneficial for consumer health. Edible coatings are of different types such as hydrocolloids, lipids and plasticizers. These have good barrier properties to O2, CO2, moisture and water vapour [12-13].

The important quality factors of fresh produce contributing to the marketability are texture, colour, appearance, flavour, nutritional value and microbial safety. These quality factors are measured by plant variety, ripening stage, maturity stage pre-harvest and post-harvest conditions The Post-harvest losses of fruits and vegetables are a serious problem because it rapidly deteriorates them during handling, transport and storage. Edible coating over fruits and vegetables are used to improve their quality and shelf life [14].

The most common and challenging problem are to maintain and control fresh quality, growth of spoilage and pathogenic microorganism in fresh cut fruit industry. The solution of this problem is edible coating form a semi-permeable barrier to gas exchange and water vapor, results in alteration of respiration rate, reduction of weight loss, and delay of senescence. In addition to acting as gas and moisture barriers, the coatings control microbial growth, preserve the texture, color and moisture of the product, and thus effectively prolong the shelf life of the product. Recently, various edible coatings were applied successfully for preserving fruits and vegetables such as orange, apples, grapefruit, cherries, cucumber, strawberry, tomato and capsicum were applied successfully. Edible coating of fruits and vegetables is successful or not totally depends on the control of internal gas composition [15-18]. This article is mainly focus on thestudy of application of chemistry in food and food industry, food additives, food preservatives, food anti-oxidant, food flavours, artificial sweeteners, Emulsifiers, stabilisers, food dyes, their examples and use.

## 2 Importance of Preservation

- Destroy pathogens for safe consumption
- Reduce the microbial load to prevent spoilage and extend shelf life of foods
- Prevent survivors from growth

## 3 Principles of preservation

Treatments to are intended to inhibit microbial growth (microbistatic), destroy irreversible inactivation, microbicidal ), to mechanically remove microorganisms, maintaining asepsis (keeping out microbes), to prevent self-decomposition of foods, inactivation of food enzymes, prevention of oxidation by anti-oxidants and applying one or combination of strategies to achieve reduction in numbers and destroying pathogens to make food safe for consumption[19].

## 4 Methods of food preservation

- Asepsis or keeping out microorganisms.
- Removal of microorganisms.
- Maintenance of anaerobic condition
- Use of high temperature
- Use of Low temperature
- Drying
- Irradiation
- Osmotic pressure
- Use of chemical preservatives
- Mechanical destruction of microorganisms.
- Combination of two or more above methods.

## 5 Chemical Methods of Preservation of Foods

Chemical preservatives are considered as food additives. A food additive is a substance or substances other than the basic food stuff which is present in food as a result of any aspect of production, processing, packaging or storage. Those food additives which are specifically added to prevent microbial spoilage, deterioration and decomposition of food are referred to as chemical preservative [20-21]. Classes of chemical preservatives: -

- Antioxidants – They inhibit the process of oxidation of unsaturated fats.
- Neutralizers – They neutralize the acidity of foods.
- Antibiotics (Antimicrobials) – They inhibit (microbiostatic) or kill microorganisms
- (microbicidal).
- Stabilizers – They prevent physical changes in food

However, chemical treatments, such as copper sulfate, rhodamine oxide, malachite green, and deadly carbide, used on green vegetables to enhance coloration and freshness, are often counterproductive to their nutritional value. Chemical food preservatives are substances which, under certain conditions, either delay the growth of microorganisms without necessarily destroying them or prevent deterioration of quality during manufacture and distribution [22].

Sulfur dioxide and sulfites are perhaps the most important inorganic chemical preservatives. Sulfites are more effective against molds than against yeasts and are widely used in the preservation of fruits and vegetables. The former group includes some natural food constituents which, when added to foods, retard or prevent the growth of microorganisms. Sugar is used partly for this purpose in making jams, jellies, and marmalades and in candying fruit. The use of vinegar and salt in pickling and of alcohol in brandying also falls in this category. Some chemicals foreign to foods are added to prevent the growth of microorganisms. The latter group includes some natural food constituents such as ascorbic acid (vitamin C), which is added to frozen peaches to prevent browning, and a long list of chemical compounds foreign to foods and classified as antioxidants, bleaching agents, acidulants, neutralizers, stabilizers, firming agents, and humectants [22-24].

### 5.1 Organic chemical preservatives

Sodium benzoate and other benzoates are among the principal chemical preservatives. The use of benzoates in certain products in prescribed quantity (usually not exceeding 0.1 percent) is permitted in most countries, some of which require a declaration of its use on the label of the food container. Since free benzoic acid actually is the active agent, benzoates must be used in an acid medium in order to be effective. The ability of cranberries to resist rapid deterioration is attributed to their high benzoic acid content. Benzoic acid is more effective against yeasts than against molds and bacteria. Other organic compounds used as preservatives include vanillic acid esters, monochloroacetic acid, propionates, sorbic acid, dehydroacetic acid, and glycols [24-27].

### 5.2 Inorganic chemical preservatives

Sulfur dioxide and sulfites are perhaps the most important inorganic chemical preservatives. Sulfites are more effective against molds than against yeasts and are widely used in the preservation of fruits and vegetables. Sulfur compounds are extensively used in wine making and, as in most other instances when this preservative is used, much care has to be exercised to keep the concentrations low in order to avoid undesirable effects on flavour. Oxidizing agents such as nitrates and nitrites are commonly used in the curing of meats [28].

## 6 Factors affecting chemical preservation

Food antimicrobials are generally bacteriostatic and fungistatic. Factors that influence preservative effect are food product, storage environment, handling and target microorganisms, concentration, stability, solubility, pH and buffering capacity.

- Organic acids: Acetic, lactic, propionic, sorbic, benzoic, citric, caprylic, malic, fumaric acids are used. Organic acids are inhibitory to Bacillus, Campylobacter jejuni, Clostridium spp., Escherichia coli, Listeria monocytogenes, Pseudomonas, Salmonella, Staphylococcus aureus.
- Acetic acid and Acetates: Acetic acid is a primary component of vinegar. Na, K, Ca salts, Na, K, Ca diacetates, dehydroacetic acid are used. Concentration of 0.1% acetic acid in bread, pH 5.1 makes shelf life- 6 days at 30oC and inhibits Bacillus subtilis growth. Sodium acetate 1% increases shelf life of catfish by 6 days at 4oC.
- Benzoic acid and Benzoates: They are used as antifungal agent. para- hydroxybenzoic acid esters (parabens), alkyl esters of benzoic acid are also used. They are antimicrobial. They are more effective against molds and yeasts and to gram positive bacteria. They interfere with function of cell membrane and have permeabilizing effect.
- Lactic acid and Lactates: Lactic acid is naturally produced by lactic acid bacteria. It is antimicrobial and flavouring agent in food products. Sodium lactate reduce contamination in beef, pork, poultry, fish. At pH 4.0 it is inhibitory to E. coli. Sodium lactate inhibits Clostridium, Yersinia Listeria and Staphylococcus aureus. Mixtures of sodium and calcium lactates (1.25 to 6%) are effective in inhibiting L. monocytogenes in sea foods.
- Propionic acid and Propionates: Upto 1% propionic acid is naturally produced in Swiss cheese by Propionibacterium freudenreichii. It is used to inhibit molds mainly; and to inhibit yeasts and bacteria. Added to bread to prevent Bacillus subtilis causing ropiness. It is used for preservation of baked foods and cheeses.
- Sorbic acid and Sorbates: Sorbic acid and sorbates are used as antimicrobial additive in foods as spray, dip, coating on packing materials. They are widely used in cheeses, baked items, beverages, fruit juices, dried fruits, pickles, margarine. they inhibit yeasts and molds; less effective against bacteria.
- Fatty Acid Esters: Glyceryl monolaurate is active against gram positive bacteria like Bacillus, Micrococcus, L. monocytogenes. They inhibit spores of Bacillus at100 μg/ml concentration.
- Nitrites: They are used as curing solutions for meats. Nitrite decomposes to nitric acid and forms nitrosomyoglobin with heme pigments in meats. So stable red color is imparted. Nitrites react with amines to form nitrosamines (carcinogenic). They are inhibitory to Clostridium botulinum and used for preservation of bacon, ham. Sodium nitrite and potassium nitrite are employed and nitrates have limited effect and not considered as good chemical preservatives and act probably as reservoirs for nitrites.
- Sulfur dioxide and Sulfites: They are used as disinfectants. Salts of SO2 like potassium sulfite and sodium sulfite are used for preservation of fruits and vegetables by controlling spoilage and fermentative yeasts and molds in wine, acetic acid bacteria and malolactic bacteria. It is used to inhibit E. coli, yeasts and fungi like Aspergillus.
- Ethylene and Propylene Oxides: Ethylene oxide exists as gas. It acts as an alkylating agent and employed as fumigant. It is applied to dried fruits, nuts, spices etc. Hydroxyl ethyl group blocks reactive groups within microbial proteins and inhibits them.
- Preservation by Salt: Salt acts as preservative when its concentration is increased above 12 per cent. Salt levels of about 18 to 25 per cent in solution generally will prevent all growth of microorganisms in foods. However, this level is rarely tolerated in foods except in the case of certain briny condiments. Salt exerts its preservative action by plasmolysis of microbial cells due to high osmotic pressure, drawing moisture from microbes, ionizing to yield chloride ion, which is harmful to microorganisms, reducing the solubility of oxygen to water, sensitizing the cells against carbon dioxide and interfering with the action of proteolytic enzymes. Salting is being done in case of meat and fish preservation. Dry salting is used in India for the preparation of preserved tamarind, raw mango, aonla, fish and meat. The preservation of food in common salt or in vinegar is known as pickling. Fruits and vegetables are preserved by pickling.
- Preservation by Sugar: Sugar in high concentrations acts as a preservative due to osmosis. Sugar attracts all available water and water is transferred from the microorganisms into the concentrated sugar syrup. The microflora is dehydrated and cannot multiply further. The concentration of sugar in sugar preserved products must be 68 per cent or more, which does not allow microorganisms to grow. Lower concentrations may be effective but for short duration unless the foods contain acid or they are refrigerated. The critical concentration of sugar required to prevent microbial growth varies with the type of microorganisms and the presence of other food constituents. Some of the most popular preserves with sugar are jelly, jam and marmalade. These are the stable gels. Pectin, a natural component of fruits, forms a gel only in the presence of sugar and acid. Sugar prevents spoilage of jams, jellies, and preserves even after the container is opened[29-34].

- Antibiotics: They are secondary metabolites produced by microorganisms. They inhibit and kill wide spectrum of other microorganisms. Molds and filamentous bacteria (Genus Streptomyces) are main producers. Two antibiotics approved for use in food: Nisin and Natamycin. Former is produced by Lactococcus lactis. It is a bacteriocin (antibiotic like) and latter is produced by Streptomyces natalensis. Aureomycin and tetracyclines are also used.
- Nisin: It is a polypeptide. It was first used in cheese to prevent spoilage by Clostridium butyricum. It is heat stable and storage stable. No off flavors are imparted but has narrow spectrum of antimicrobial activity. It is used as heat adjunct in canned foods and typical levels incorporated in foods are 2.5 to 100 ppm. It s mode of action is prevention of germination of spores and act on cell membrane lipids. It inhibits gram positive bacteria[35-39].
- Natamycin: This antibiotic is a polyene produced by Streptomyces natalensis. It is effective against yeasts and molds at 1 to 25 ppm levels and control growth of fungi in strawberries and raspberries. Mode of action is it binds membrane sterols and induces distortion of selective membrane permeability. Bacteria are insensitive to natamycin due to lack of membrane sterols. Other antibiotics tried for food applications include tetracyclines: chlor- and oxytetracyclines as approved by FDA at 1 to 7ppm level in uncooked refrigerated poultry to control bacterial spoilage.
- Antifungal Agents for Fruits: Compound - Thiabendazole is used for preservation of Apples, pears, pineapples. Biphenyl are used for preservation of Citrus fruits. They are applied to fresh fruits after harvest on surface at 0.5 to 1 g/L levels.

Chemical preservatives are intentional food additives incorporated into food to prevent or retard food spoilage caused by microbiological, enzymological, or chemical reactions. These chemical preservatives should be nontoxic to humans or animals. Chemical preservatives come under the food additives generally recognized as safe (GRAS). Chemical preservatives can also be termed antimicrobials. The main purpose of using chemical preservatives is to inhibit the growth and activity of food borne pathogens and spoilage microorganisms. Chemical preservatives used in food can have both bacteriostatic and bactericidal properties per the concentration used [39-44].

Role of chemical preservatives: Interferes with the cell wall, cell membrane, enzymatic activity, nucleic acids, etc., to prevent microorganisms' growth and activity. Retard, prevent or control undesirable changes in flavor, color, texture, or consistency of food and nutritive value of food.Control natural spoilage of food [44-46].

## 7 Classification of chemical preservatives

- Class I: Traditional preservatives (natural)
- Class II: Chemical preservatives (Artificial)

Class I: Traditional Preservatives: These include preservatives like wood, smoke, sugar, honey, salt, spices, alcohol, vinegar, vegetable oil, spices, etc which are commonly used in our kitchen in past. These chemical preservatives are not restricted to use and there is no imposed limitation on their use. These naturally occurring preservatives are regarded as safe for human health.

Class II: Chemical preservatives: These are synthetic chemical preservatives that are made in the laboratory. For e.g nitrites, propionates, parabens, benzoates, acetates, sorbates, sulfur dioxide, etc [47-50].

Microbial preservatives: These include antimicrobial preservatives like bacteriocins (e.g. nicin) which are produced by some strains of lactic acid bacteria and inhibit the growth of food spoilage or pathogenic bacteria. E.g nisin, produced by *lactococcus lactis* inhibits the growth of *Clostridium tyrobutyricum, C. botulinum, and, listeria monocytogenes* in cheese, other dairy products meats, fish, etc.Using bacteriocins like microbial preservatives help reduce the use of chemical preservatives like nitrates, sorbates, and benzoates which consumers consider bad [51].

## 8 Factors affecting the effectiveness of chemical preservatives

### 8.1 Chemical preservative properties (Figure- 1)

- Solubility
- Toxicity

### 8.2 Microbial factors

- Microbial inherent resistance to chemical preservatives
- Initial microbial load
- Growth rate and phase of microorganisms
- Stress reaction of microorganisms
- Homeostasis ability of microorganisms
- Use of additional preservative methods

### 8.3 Intrinsic factors of food

- pH of the food
- Water activity of food

### 8.4 Extrinsic factors

- Storage time and temperature
- Gas composition
- Atmosphere and relative humidity

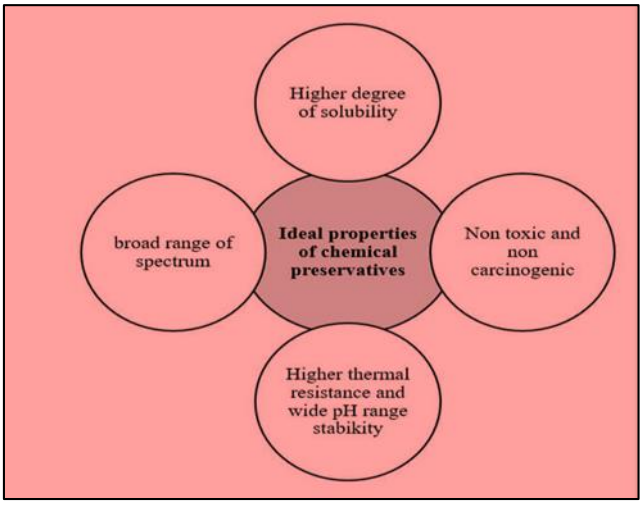



**Figure 1** Preservative properties

## 9 Chemical preservatives and their application in the food industry

All the parts of food in canning food preservation are chemicals. People eat the majority of their food made up of chemicals called carbs, fat, proteins, minerals, and water. The vitamins and natural antioxidants, antimycotics, buffers, thickeners, emulsifiers, chelating agents, colours, and flavours are just a few of the small amounts of other chemicals found in food [52].

Many chemicals are added critically to make food more appealing and last longer. There are a lot of food additives out there. Still, the main ones are food colours and sweeteners, antioxidants, fat emulsifiers, stabilising agents, flour improvers (like gluten), food preservatives, and nutritional supplements like minerals, vitamins, and amino acids. Only a nutritional supplement has any nutritional value, and nothing else has it. Many types of chemicals listed below are used nowadays as food preservatives **[**53-55**]**.

## 10 Food additives

Food additives are food preservatives that are added to improve the look, taste, or even to keep the flavours of the food. Some of them, such as sugar and salt showing in table 1, are naturally occurring flavours. However, chemists have developed many different flavours, and methyl salicylate is one of them [55-59].

The following are examples of significant food additives:

- Food colours
- Preservatives
- Enzymes
- Artificial flavours and sweeteners

### 10.1 Colouring Agent for Food Colorings

The colourant is used as a chemical in food to alter a food substance's appearance. Colours can be found in nature and those that have been purposefully created. Caramel is an example of a naturally occurring food colour, whereas caramel colouring is an example of an artificially created food colour.

### 10.2 Preservatives

Antibacterial, antifungal, and antimicrobial preservatives are chemicals used to preserve food against bacteria, yeast, and mould. Both Class-I and Class-II are subdivided into two groups: I and II, respectively. Salt, sugar, and vegetable oils are examples of class-I preservatives. Preservatives belonging to the Class II family are listed below in alphabetical order.

#### *10.2.1 Sodium benzoate*

Sodium benzoate is the widest variety of preservatives used in the food market. It is also the most expensive. It is utilised as a flavouring agent in soft drinks and acidic dishes.

#### *10.2.2 Sodium metabisulphite*

Foods like jams, pickles, squashes, and similar items are preserved with sodium metabisulphite.

#### *10.2.3 Sorbic acid*

Mould and yeast development are inhibited by using sorbic acid and its salts. Sorbic acid is a powerful antifungal agent. A variety of items, including cheese, baked goods, and some meats, are treated to keep yeasts and moulds from growing.

### 10.3 Enzymes

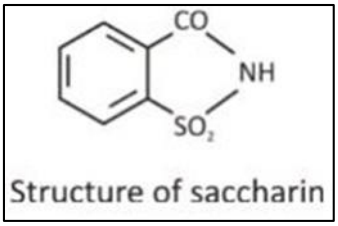
When it comes to converting processes from one material to another, enzymes are biological catalysts that are utilised. The enzymes participating in a chemical process reduce the energy and time necessary to finish. Food processing companies employ enzymes in manufacturing food preservatives items such as dairy products, fruit juices, beer, bread, and other baked goods.

### 10.4 Artificial Sweeteners

Sucrose and fructose are two of the most common natural sweeteners. Many people use artificial sweeteners because they add calories and cause tooth decay. For example, some of them are saccharin, aspartame, alitame, sucralose, cyclamate, and L-glucose.

#### *10.4.1 Saccharin*

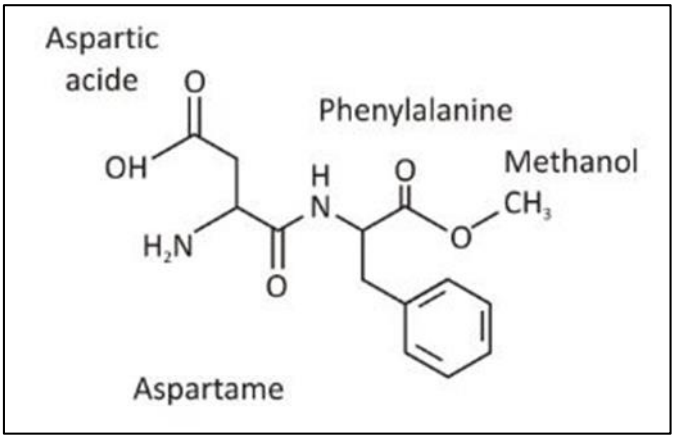
It is one of the most widely used sweetening compounds, and it may be found in a variety of items, including beverages, sweets, pharmaceuticals, and toothpaste. However, it has a severe bitter (or metallic) aftertaste at high concentrations 550 times sweeter than cane sugar.



Structure of saccharin

*10.4.2 Aspartame*

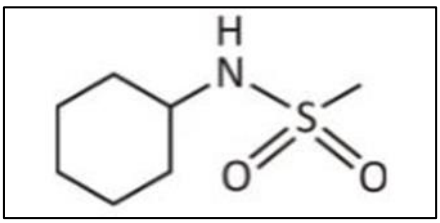
Sodium aspartate is an amino acid dipeptide created by combining aspartic acid and phenylalanine to form aspartame. It is a non-saccharide sweetener that is around 200 times sweeter than cane sugar in terms of sweetness. A sweet flavour is there, but there is no unpleasant chemical (or) metallic aftertaste that has been seen with other artificial sweeteners.



Aspartame

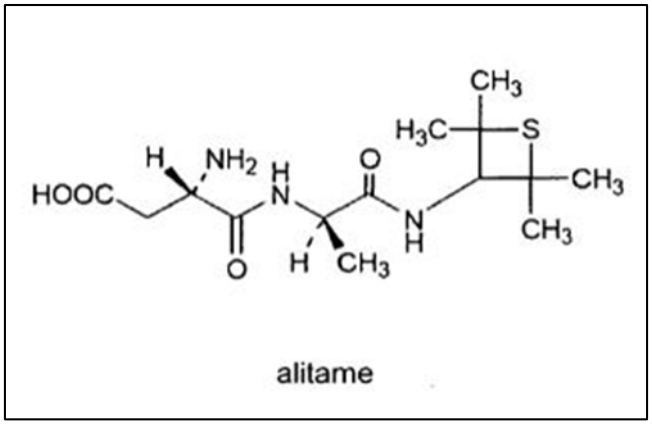
*10.4.3 Cyclamate*

Cyclamate has a sweetness that is approximately seven times greater than sucrose in terms of sweetness. Researchers discovered that the combined sweetness of cyclamate and saccharin (10:1) was si gnificantly sweeter than either of the two substances alone.



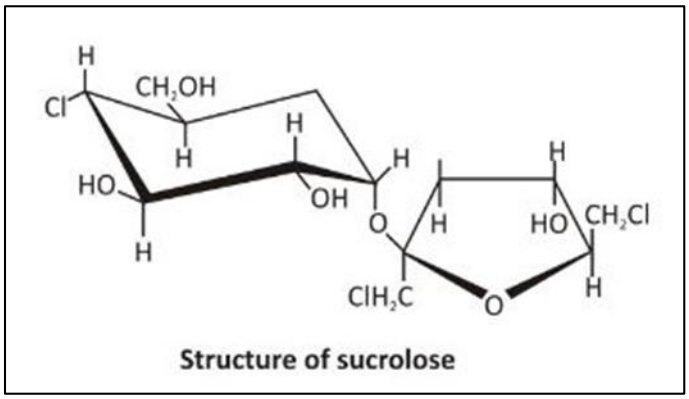

*10.4.4 Alitame*

Alitamame is an artificial sweetener composed of aspartic acid and alanine as part of a dipeptide bonding. It is thought that the new amine is attached to the alanine moiety of alitame. It is responsible for the increased sweetness and potency of alitame. Compared to sucrose, alitame is approximately 2000 times sweeter and is more stable than aspartame. The sweetness of food is challenging to manage when it is used as an artificial sweetener under the circumstance of high intensity of the sweetener used.




*10.4.5 Sucralose*

A trichloro-derivative of sucrose, it is a sweetener used in baking. When cooked at the appropriate temperature, it has the appearance and flavour of sucrose. In addition to being about 600 times sweeter than sucrose, it has no known adverse effects on tooth decay or illness.




## 10.5 Advantages of Food Preservatives

- The nutritional content of food can be improved or maintained by adding certain additions to the recipe.
- Ensures that food remains fresh for significantly more extended periods
- Making seasonal vegetables and fruits available all year long saves time and money.
- Cheaper
- Increase the nutritional value of food, for example, by adding vitamin C to bread.
- For example, using a sweetener instead of sugar can help you consume fewer calories overall.

## 10.6 Disadvantages of Food Preservatives

- ADHD and other behavioural disorders have been linked to this condition.
- An allergic response can occur in certain persons, especially youngsters.
- As of yet, there is no proof that there is a relationship between the two.
- Asthma-related links may hurt specific individuals
- High blood pressure is a problem that may exacerbate.
- In canning food preservation, it is used instead of genuine ingredients. The food is less healthy.
- Calories may be more abundant [60].

**Table 1** Different chemical preservatives and their application in the food industry

| S.N | Chemical preservatives | Targeted microorganisms | Mode of action | Advantages | Disadvantages Applications | |
|---|---|---|---|---|---|---|
| 1 | Sulfur dioxide ($SO_2$) | Yeast, mold | Increase pH and imbalance cellular metabolic process, alter the enzymatic system, | Antioxidant properties, prevent browning, preserve color, cheaper and easily available | The intense pungent odor and corrosive property makes it unuseful in canning | Beverages, fruits products, heat-sensitive foods, effective for low pH foods |
| 2 | Sorbates(Sodium sorbate and Potassium sorbate) | Yeast, Mold, Bacteria | Disturb enzyme system, inhibit many enzymes involved in TCA cycle | | | Beverages; juices, wines, cheese, fish meat bakery items, |
| 3 | Benzoic acid and benzoates | Yeast, molds | Disturb enzymatic system | Most active against yeasts and molds.<br>Used to preserve colored fruit juices | Risk of respiratory disease | High acid foods, fruit drinks, cider, carbonated beverages, pickles, jams, salad dressings, soy sauce |
| 4 | Parabens (p-hydroxybenzoic acid) | Yeast, Mold, bacteria | Destroy complex structure of the cell and denature protein inside the cell | | | Soft drinks, fish products, salad dressing |
| 5 | Propionic acid | Mold, yeast, and a few bacteria | Disturb enzyme system | | | Low acid foods, processed cheese preservation |
| 6 | Nitrate and nitrite | Anaerobic bacteria *(Clostridium botulinum*), other pathogenic microbes | Inhibit metabolic enzyme | Preserve the color of red meat by forming nitrosomyoglobin | The formation of carcinogenic nitrosamines is triggering extensive research | Used in cured meats, better at low pH foods |
| 7 | Phosphates | More against gram-positive bacteria (*Bacillus, clostridium*) | Chelating metal ions | | | |
| 8 | Sulfites | More Bacteria, less effective to yeast and mold | Target to the cytoplasmic membrane, DNA | Acts as antioxidants and inhibit enzymatic browning | | Fruits and vegetable products, wine |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | replication, protein synthesis, and enzymatic actions | | | |
| 9 | Sodium chloride (NaCl) | Bacteria | Osmotic shock to Plasmolysis | Better preservation if used as a pretreatment before canning, pasteurization, or drying | Weak against *Staphylococcus* and *listeria monocytogens* | Salting of meats and fish |
| 10 | Wood smoke (Traditional method) | Bacteria, fungi | The release of different phenolic compounds, ketones, aldehyde, and alcohol, which serves as an antimicrobial preservative | Easy to use | | Meat, sausage, ham, bacon, fish |
| 11 | Nisin | Clostridium botulinum and other bacteria | | | | |

## 11 The working mechanism of organic acids on the bacterial cell

Organic acids like Acetic acid, benzoic acid, lactic acid, propionic acid, sorbic acid, etc., are effective as preservatives for foods with a pH of less than 5. So, they are the best for preserving acidic foods showing in Table 2 [60-61].

- At acidic pH, protonated or uncharged organic acid crosses the cell membrane and enters the cytoplasm.
- In neutral cytoplasmic pH, organic acids dissociate and release the proton that acidifies the cytoplasm.
- This cell uses ATP to pump protons out of the cell to deacidify the cytoplasm, which makes energy unavailable for their growth.

**Table 2** Guidelines for using chemical preservatives in food

| S.N. | Food | Preservatives | PPM |
|---|---|---|---|
| 1 | Sausage meat containing raw meat, Cereals, spices | Sulfur dioxide | 450 |
| 2 | Undried fruits: Cherries, Strawberries, and raspberries.Other fruits | Sulfur dioxide | 2000<br>1000 |
| 3 | Concentrated fruit juice | Sulfur dioxide | 1500 |
| 4 | Dried fruits | Sulfur dioxide | 1500 |
| 5 | Apricots, peaches, apples, pears | Sulfur dioxide | 2000 |
| 6 | Sugar, dextrose, jaggery, refined sugar | Sulfur dioxide | 70 |
| 7 | Beer | Sulfur dioxide | 70 |
| 8 | Cider | Sulfur dioxide | 200 |
| 9 | Alcoholic wine | Sulfur dioxide | 450 |

| | | | |
|---|---|---|---|
| 10 | Dried ginger | Sulfur dioxide | 2000 |
| 11 | Squash, fruit syrups, barley water | Sulfur dioxide, or<br>benzoic acid | 350<br>600 |
| 12 | Pickles | Sulfur dioxide, or<br>benzoic acid | 250<br>100 |
| 13 | Jam, marmalade, fruit jelly | Sulfur dioxide, orbenzoic acid | 40 200 |
| 14 | Coffee extract | Benzoic acid | 120 |
| 15 | Tomato or other juices | Benzoic acid | 750 |
| 16 | Pickled meat, bacon, canned meat | Sodium nitrite or potassium nitrite | 200 |
| 17 | Cheese or processed cheese | Sorbic acid or Sodium sorbate or potassium sorbate | 3000 |
| 18 | Paneer | Sorbic acid or Sodium sorbate or potassium sorbate | 2000 |
| 19 | Flour confectionery | Sorbic acid or Sodium sorbate or potassium sorbate | 1500 |
| 20 | Baking flour | Sodium diacetate,<br>Propionates,<br>Methyl propyl hydroxybenzoate | 2500<br>3200<br>500 |

## 12 Food Dyes

- Food Dyes are found in:
- Examples: Erythrosine, a cherry-red colouring commonly used in candy, popsicles and cake-decorating gels. Allura Red, a dark red dye that is used in sports drinks, candy, condiments and cereals.
- With the advent of food chemistry, we now have a wide range of artificial food colours as additives.
- Carotenoids have a deep red, yellow, or orange colour. It is found in carrots, tomatoes etc. If you eat too many foods that contain beta-carotene, your skin may turn orange.
- Examples of the most common ones are as follows: chlorophyll, anthocyanin, and turmeric.
- Food Dyes are used to colouring foods. Natural dyes have been used to colour food for centuries [62-63].
    - Instant flavoured Oatmeal.
    - Salad Dressings.
    - Cereals.
    - Syrup.
    - Candies and Chocolates.
    - Artificially Flavored Drinks and Juices.
    - Frozen Treats.

## 13 Food Sweeteners [63-66]

- They are added either for the purpose of enhancing the safety of the stored food or to enhance its beauty.
- Cane sugar, glucose, maltose, fructose are all sweeteners that occur in plants. They are natural sweeteners.
- Besides sweetness, they also serve as food i.e. Natural sweeteners such as sucrose increase the calories consumed. Certain chemicals which do not occur in nature but are synthesized in the laboratory have a sweet taste, but they have no food value.
- They are known as artificial sweeteners.

### *13.1.1 Saccharin*

- Ortho Sulfo Benzamide, also known as saccharin, is the first popular artificial sweetener. The artificial sweetener was discovered by Constantine Fahlberg and Era Ramsen in 1879. It was an important discovery for diabetics. It goes directly through the human digestive system without being digested. Its use is very important for patients with diabetes and those who need to control calorie intake.

- At high concentrations, it has an unpleasant bitter taste. The molecular formula of Saccharin is $C7H5NO3S$
- It is 550 times sweeter than cane sugar. It is used to sweeten the products like medicine, toothpaste, low-calorie sweets, soft drinks, cold drinks, etc.

#### *13.1.2 Aspartame*

- Aspartame is the most successful and widely used synthetic sweetener.
- It is about 100 times sweeter than sucrose.
- It is a Methyl Ester of a dipeptide made of Aspartic Acid and Phenylalanine.
- Its use is limited to cold foods and beverages only.

#### *13.1.3 Alitem*

- Alitem is a more potent sweetener.
- It is more permanent than aspartame.
- It is difficult to control sweetness when used.

#### *13.1.4 Sucralose*

- Sucralose is a trichloro derivative of sucrose.
- Its form – colour and taste are like sugar.
- It is stable at cooking temperature.
- It does not give calories.

## 14 Regulation and Safety Considerations

### 14.1 Government Regulations on Food Preservatives [67]

- Government regulatory bodies, such as the FDA in the United States and the EFSA in the European Union, establish regulations and guidelines for the use of food preservatives.
- These regulations ensure that preservatives used in food products are safe, effective, and within acceptable limits.

### 14.2 Acceptable Daily Intake (ADI) and Maximum Residue Limits (MRL)

- ADI refers to the estimated amount of a food additive, including preservatives, that can be consumed daily over a lifetime without adverse health effects.
- MRL specifies the maximum allowable residue levels of preservatives in food products to ensure consumer safety.
- Regulatory authorities set ADI and MRL based on extensive toxicological studies and risk assessments.

### 14.3 Potential Health Risks and Controversies

- While preservatives undergo rigorous safety assessments, some concerns and controversies have arisen regarding their potential health risks.
- For example, certain preservatives, when combined with specific ingredients or under certain conditions, may lead to the formation of potentially harmful substances, such as benzene or nitrosamines.
- Regulatory bodies continuously monitor scientific research and conduct risk assessments to address any potential health risks associated with preservatives.

### 14.4 Labelling Requirements for Food Products

- Labelling requirements mandate that food products indicate the presence of specific preservatives to inform consumers and allow them to make informed choices.
- Manufacturers must accurately list the preservatives used, either by their specific names or their corresponding E-numbers, on the product labels.
- Additionally, labelling may include allergy warnings for preservatives known to cause allergic reactions in some individuals.

By enforcing government regulations, establishing ADI and MRL, addressing potential health risks, and implementing labelling requirements, regulatory bodies ensure the safe use of food preservatives and enable consumers to make informed decisions about the products they consume. These measures contribute to maintaining food safety and protecting public health [68].

## 15 Conclusions

- Chemistry has helped the modern world in a lot of different ways. Food preservatives have made a big difference in eating food every day. They help keep the food safe. Most of the food we buy at the store has a shelf life of a few months to a few years. These foods can only stay fresh because they add these chemicals to prevent spoilage.
- Interferes with the cell wall, cell membrane, enzymatic activity, nucleic acids, etc., to prevent microorganisms' growth and activity. Retard, prevent or control undesirable changes in flavor, color, texture, or consistency of food and nutritive value of food.Control natural spoilage of food.
- Food additive preservatives are still necessary to ensure the safety and variety of different foodstuffs available. They function through delaying the spoiling of foodstuffs and preventing any alterations in their taste or appearance.
- Edible coating is an effective method to solve this problem. It provides protective edible covering to fruits and vegetables. It is beneficial for consumers and environment. Today herbal edible coatings are used as a nutraceuticals and beneficial for consumer health.
- By enforcing government regulations, establishing ADI and MRL, these measures contribute to maintaining food safety and protecting public health.

## Compliance with ethical standards

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