Paper No.: 13

Paper Title: FOOD ADDITIVES

Module – 15: Preservatives and antimicrobial agents for the food industry

15.1 INTRODUCTION

Since ancient times, chemicals have been added to preserve freshly harvested foods for later use. Drying, cooling, fermenting, and heating have always been the primary methods used to prolong the shelf life of food products. Whereas some chemical food preservatives, such as salt, nitrites, and sulfites, have been in use for many years, most others have seen extensive use only recently. One of the reasons for increased use of chemical preservatives has been the change in the ways foods are produced and marketed. Today, consumers expect foods to be readily available, free of foodborne pathogens, and to have a reasonably long shelf life. Although some improvements have been made using packaging and processing systems to preserve foods, preservatives and antimicrobial play a significant role in protecting the food supply. In addition, because of changes in the marketing for foods to a more global system, products seldom are grown and sold locally as in the past. Today, foods produced in one area are often shipped to another area for processing and to several other areas for distribution. Several months or years may elapse from the time food is produced until it is consumed. To accomplish the long-term shelf life necessary for such a marketing system, multiple effective means of preservation are often required. It is important to note that, with rare exceptions, food preservatives and antimicrobials are not able to conceal spoilage of a food product (i.e., the food remains wholesome during its extended shelf life). In addition, because food preservatives and antimicrobials are generally bacteriostatic or fungistatic, they will not preserve a food indefinitely.

Food antimicrobials are classified itself as “preservatives.” Chemical preservatives are defined by the U.S. Food and Drug Administration “any chemical that, when added to food, tends to prevent or retard deterioration thereof, but does not include common salt, sugars, vinegars, spices, or oils extracted from spices, substances added to food by direct exposure thereof to wood smoke, or chemicals applied for their insecticidal or herbicidal properties.” Therefore, preservatives are used to prevent or retard both chemical and biological deterioration of foods. Those additives used to prevent biological deterioration are termed “antimicrobials.” The FDA defines antimicrobial agents as “substances used to preserve food by preventing growth of microorganisms and subsequent spoilage, including fungistats, mold and rope inhibitors.” The traditional function of food antimicrobials is to prolong shelf life and preserve quality through inhibition of spoilage microorganisms. However, antimicrobials have been used increasingly as a primary intervention for inhibition or inactivation of pathogenic microorganisms in foods.

15.2 PRESERVATIVES

Preservative for food in general may be defined as any chemical compound, when applied to food, retard alterations caused by the growth of microorganisms or enable the physical properties, chemical composition and nutritive value to remain unaffected by microbial growth. Some chemical have been used traditionally since several decades as direct or indirect inhibitors of microbial growth and are still widely used despite their limitations.

Preservatives play a very important role in the food industry, from manufacture through distribution to the ultimate consumer. The choice of a preservative takes into consideration the product to be preserved, the type of spoilage organism endemic to it, the pH of the product, period of shelf life, and ease of application. No one preservativecan be used in every product to control all organisms, and therefore combinations are often used. In certain foods, specific preservatives have very little competition. In the concentrations used in practice, none of the preservatives is lethal to microorganisms in foods. Rather, their action is inhibitory.

15.2.1 Preservatives should fulfill the following requirements.

- Simple and economical compounds and available easily
- Have good inhibitory action against a wide range of microorganisms
- Have low order of toxicity - safe and no carcinogenic
- Have high stability in the environment of food in which it is added - pH, temperature, redox potential, moisture etc.
- Do not alter the identity and quality of the product
- Should be practical and compatible with product processing
- Should not adversely affect the nutritive value of the product
- Should have sufficient solubility in the medium prevailing in the food

15.2.2 Major factors that decides the choice of preservative for food

- Composition of food
- Environment - pH, temperature, redox potential etc.

- Type of microorganisms that are likely to grow (because selective action)
- Processing and storage conditions
- Solubility, flavour etc.
- Availability, cost effectiveness, legality etc

15.2.3 Precautions to be observed when preservatives added to the food

- Preservative should be added in the batch soon after the fruits or vegetables are crushed or the batch is mixed. Any delay causes microorganisms to start growing. Even a few hours delay may permit fermentation to begin and produce enzymes. These enzymes continue to deteriorate the product even after addition of preservative.
- If the product is boiled/concentrated (e.g. ketchup), the preservative is best added a few minutes before batch is ready. A few minutes of boiling after the addition will help in thorough mixing.
- If it is water soluble, always add it in solution for to avoid uneven dispersion in food. If powder is added, it first stable at out and fermentation may begin before its solution is complete. Problem of local effect - excessive at one point and inefficient at others.
- In case of very thick viscous product dissolve the preservative in water and add the viscous ingredient at the last. Then mix the product thoroughly to ensure it even distribution.
- In preserving fruit pulp etc. the fruit cells does not absorb preservative readily and will float on top. So shake them a couple of times of a day or two so that they get fully impregnated with preservative.
- Clean all receptacles such as bottles, carboys and barrels thoroughly with steam, hot water or 0.02% solution of sodium hydrochloride.
- The characteristic of raw material, processing treatments and storage conditions determine the amount of preservative needed. It cannot compensate with poor factory hygiene. Once product is heavily contaminated preservation is no longer possible.
- For getting maximum benefit of preservative it is necessary to use in the conjugation with good sanitary practices.

15.2.4 Mode of action of preservative

The preservative may function through one or more of the following way:

- React with amine (-NH2) group of proteins and nucleic acids - change their property → HCHO

- Inactivate the enzyme(s) system of the microorganisms - physiological process adversely affected → HCHO
- Liberation of nascent (active) oxygen which oxidizes certain amino acids (e.g. cystine, methionine, tyrosine etc.) and aldehydes into ketons and acids→ H_2O_2, proteins and enzymes are adversely affected
- Raising the redox potential to a level which is not suitable for microbial growth. By addition of oxidizing agents → H_2O_2, nitrate etc.
- Change (lower) the pH of the medium (food) to an extent at which microorganisms are not able to grow. Acidulants → acetic acid, lactic acid etc.
- Neutralize the acid produced by microbial activity - neutralizers → bicarbonates and carbonates
- Acts as an antivitamins and make them unavailable as coenzymes for enzyme activity - antagonist to vitamin → benzoic acid, salicylic acid etc.
- Makes the water unavailable or reduce the amount of water available for bacterial activity and even may cause dehydration of microbial cell → salt, sugar etc.
- Make some micronutrients (trace elements such Zn and some vitamins such as B group, K etc.) unavailable to microorganisms which is very necessary for their growth and physiological activity → chelating agents
- Interfere in electron and/or nutrients transfer system of the microbial cells → ester of p-hydroxy benzoic acid, sorbic acid
- Inhibition of synthesis of protein, DNA, RNA etc. → ester of p-hydroxy benzoic acid

15.2.5 Classification of preservatives

Broadly preservatives are divided into two categories i.e., Class I & Class II

15.2.5.1 Class I preservatives

Example: Common salt, Sugar, Dextrose, Glucose, Spices, Vinegar or acetic acid, Honey, Edible vegetable oil etc.

Addition of class I preservatives in any food is not restricted, unless otherwise provide in the rule

15.2.5.2 Class II preservatives

Example: Benzoic acid including salts theirof, Sulphurous acid including salts theirof, [Nitrates of] nitrites of sodium or potassium, Sorbic acid including its sodium, potassium and calcium salts, Nisin, Propionic acid including salts theirof, Methyl or propyl para-hydroxy benzoate, Sodium diacetate, Sodium, potassium and calcium salts of lactic acid etc.

Use of class II preservatives is restricted. They shall be added to only specified product and at a concentration not exceeding the proportion specified for the product.

15.3 ANTIMICROBIAL AGENTS

Humans have attempted to preserve food products from the detrimental effects of micro-organisms since prehistoric times. Processes such as heating, drying, fermentation, and refrigeration have been used to prolong the shelf-life of food products. Some chemical food preservatives, such as salt, nitrites, and sulfites, have been in use for many years, however some have seen extensive use only recently. One of the reasons for the increased use of chemical preservatives has been the changes in the ways foods are produced and marketed. Today, consumers expect foods to be available year-round, to be free of food- borne pathogens, and to have a reasonably long shelf-life. While some improvements have been made using packaging and processing systems to preserve foods without chemicals, today antimicrobial food preservatives still play a significant role in protecting the food supply.

Antimicrobials are capable of retarding or preventing growth of microorganisms such as yeast, bacteria, molds, or fungi and subsequent spoilage of foods. The principal mechanisms are reduced water availability and increased acidity. Sometimes these additives also preserve other important food characteristics such as flavor, color, texture, and nutritional value. The primary food additives used for this function are sorbic acid, potassium and sodium sorbates, calcium and sodium propionates, benzoic acid, sodium and potassium benzoates and parabens. In addition to these compounds, several organic acids such as citric, malic, lactic, ascorbic, phosphoric, and tartaric also act as antimicrobial agents. Sulfur dioxide and sulfites are also applied extensively for controlling undesirable microorganisms in soft drinks, juices, wine, beer, and other products.

15.3.1 Factors must be taken into consideration in selecting a food antimicrobial agent

- The antimicrobial spectrum of the compound to be used must be known. This, along with knowledge of the bio-burden of the food product, will allow the use of correct antimicrobial agent for the microorganism(s) of concern.
- The chemical and physical properties of both the antimicrobial and the food product must be known. Such factors as pKa and solubility of the antimicrobial and the pH of the food will facilitate the most efficient use of an antimicrobial.

- The storage conditions of the product and interactions with other processes must be evaluated to ensure that the antimicrobial will remain functional over time.
- Food must be of the highest microbiological quality initially if an antimicrobial is to be expected to contribute to its shelf-life. None of the antimicrobials is able to preserve a product that is grossly contaminated. Because food antimicrobials are generally bacteriostatic or fungistatic, they will not preserve a food indefinitely. Depending upon storage conditions, the food product will eventually spoil or become hazardous.
- The toxicological safety and regulatory status of the selected compound must be known.

Table 15.1: Traditional Food Antimicrobials

Compound(s)	**Microbial Target**	**Primary Food Applications**
Acetic acid, acetates, diacetates, dehydroacetic acid	Yeasts, bacteria	Baked goods, condiments, confections, dairy products, fats/oils, meats, sauces
Benzoic acid, benzoates	Yeasts, molds	Beverages, fruit products, margarine
Dimethyl dicarbonate	Yeasts	Beverages
Lactic acid, lactates	Bacteria	Meats, fermented foods
Lactoferrin	Bacteria	Meats
Lysozyme	*Clostridium botulinum*, other bacteria	Cheese, casings for frankfurters, cooked meat, and poultry products
Natamycin	Molds	Cheese
Nisin	*Clostridium botulinum*, other bacteria	Cheese, cooked meat and poultry products
Nitrite, nitrate	*Clostridium botulinum*	Cured meats
Parabens (alkyl esters (propyl, methyl, heptyl) of p -hydroxybenzoic acid)	Yeasts, molds, bacteria (Gram positive)	Beverages, baked goods, syrups, dry sausage

Propionic acid, propionates	Molds	Bakery products, dairy products
Sorbic acid, sorbates	Yeasts, molds, bacteria	Most foods, beverages, wines
Sulfites	Yeasts, molds	Fruits, fruit products, potato products, wines

15.3.2 Important Preservatives and Antimicrobials are discussed below.

15.3.2.1 Benzoic acid and its sodium benzoate salts: They are most effective against yeast and mold. They are used in beverages, fruit products, chemically leavened baked goods, and condiments. Owing to their inhibitory effect on yeast, they cannot be used in yeast-leavened products. Potassium benzoate was developed for use in reduced-sodium products. Benzoates are permitted for use in foods up to a level of 0.1%.

15.3.2.2 Sorbic acid and its sodium and potassium salts: They are used as mold and yeast inhibitors in dairy products, chemically leavened baked goods, fresh and fermented vegetables, dried fruit, beverages, confections, and smoked meat and fish, and are effective in the acidic pH range up to pH 6.5. Sorbates have the ability to inhibit the growth of yeast at the surface of food during fermentation, but do not inhibit the organisms that are used inthe fermentation process. Sorbates are typically added directly by dipping the food into a sorbate solution, or by spraying them on the surface of the food. Usage ranges from 0.025 to 0.2%.

15.3.2.3 Propionic acid and its calcium and sodium salts: They are effective mold inhibitors. They are particularly useful in yeast-leavened baked products because they do not affect the activity of yeast. In addition to being widely used in baked goods, they are used as mold inhibitors in cheese foods and spreads.

15.3.2.4 Parabens: They are used as preservatives. Unlike other antimicrobials, the parabens are active up to a pH 8. They are used as mold and yeast inhibitors in baked goods, beverages, fruits, jams, syrups, olives and pickles. Parabens are effective in low-acid foods (pH greater than 5.0), such as meat and poultry products.

15.3.2.5 Organic acids: One method of controlling the growth of microorganisms in food is to increase the acidity of the product. This can be accomplished by adding an organic acid such as acetic acid citric acid, malic acid, lactic acid, adipic acid, tartaric acid or caprylic acid. Because acids can affect the functionality of other ingredients in food, care must be taken in selecting the appropriate one. These acids also function as acidulants.

15.3.2.6 Sulfur dioxide and sulfite salts: (e.g., potassium sulphite, potassium metabisulfite, sodium bisulfite, sodium metabisulfite and sodium sulphite). They are the most effective inhibitors of deterioration of dried fruits and fruit juices. Sulfur compounds also used in the fermentation industry to prevent spoilage by microorganisms and as a selective inhibitor of undesirable organisms.

15.3.2.7 Nitrates and nitrites: They are used in the meat-curing processes to prevent the growth of bacteria that cause botulism. Nitrates have been shown to form low, but possibly toxic, levels of nitrosamines in certain cured meats. For this reason, the safety of these products has been questioned, and use is limited.

15.3.2.8 Natural alternatives: Concern over the safety of synthetic preservatives has led to the research and development of natural alternatives.

Natamycin: Natamycin an antibiotic produced by *Streptomyces natalensis*, has gained popularity for use against molds on cured cheeses. Natamycin selectively inhibits molds while allowing the growth of bacteria needed for the ripening process.

Nisin: Nisin, a polypeptide produced by the fermentation of a modified milk medium by *Lactococcus lactis*, is particularly effective against spore-forming gram-positive bacteria. It is used worldwide as a preservative in processed cheese, dairy products, canned foods, cured meat and beer.

Salt, sugar, alcohol, spices, essential oils, and herbs also inhibit growth of microorganisms, but usually their primary function is different when added to food.

15.4 FUTURE SCOPE

Preservatives and antimicrobials will undoubtedly continue to be needed to provide the food supply that will be demanded in the future. The global economy in which we live results in foods being

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transported throughout the world. If foods are to arrive in the condition expected, preservatives will be needed. This will also require the development of uniform worldwide regulations regarding the use of these chemicals in food products. The future of research in the area of food preservatives and antimicrobials will likely be on two fronts. First is the expansion of information on the antimicrobial spectrum of natural antimicrobials. This research will be more focused on the appropriate use of natural antimicrobials or utilization of compounds in situations in which they are compatible. A second major area of research involves use of preservatives and antimicrobials in combinations with each other and with traditional or novel processing methods. To more effectively apply such chemical compounds so that synergistic activity is possible will require knowledge of the mechanisms of action of the compounds. In addition, natural antimicrobials will be increasingly looked on as adjuncts in hurdle technology and used with milder non-sterilizing, non-thermal processing methods such as high hydrostatic pressure or pulsed electric fields.

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