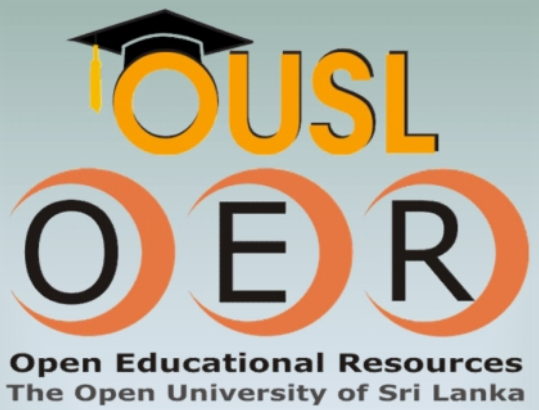

Food additives

Department of Chemistry
The Open University of Sri Lanka

Food additives

Introduction

In previous lessons, we considered the chemistry of synthetic polymers, natural polymers and biomolecules such as carbohydrates, amino acids, proteins, fatty acids and lipids. In this lesson, we intend to study pros and cons of food additives. People around the world use natural and artificial food additives particularly to improve the taste and appearance of food without thinking of their effects on their health. **Do you have the practice of checking the list of food additives given in the label when you buy food items?**

Centuries ago and even today people smoke fish/meat and add certain chemicals to them (*e.g.* salt) to improve their shelf life. Particularly in eastern countries, people add spices and indigenous herbs to food to improve its taste and colour. Some food varieties are seasonal (and abundant during the season) and are not available throughout the year. But preserved food is made available around the year, enabling us to enjoy food in different forms, even in places where it is not available or produced.

Consumption of food additives may have certain **health risks**. Carcinogenesis (*i.e.* causation of cancers), hyperactivity in children, precipitation of allergies, and migraine are some known health risks associated with food additives. **It is high time you knew more about what you eat.**

Let us examine the **definition of a food additive**. Food additives can be defined as chemical substances deliberately added to food, directly or indirectly, in known or regulated quantities, for purposes of assisting in the processing of food, preservation of food, or in improving the flavour, texture, or appearance of food. The food additives can be classified into preservatives, antioxidants, flavours, flavour enhancers, food colourings, sweeteners, vitamins, *etc*. *Let us first consider the method used for the identification of various food additives by means of a number*.

1. E-numbers

Thousands of food additives are known with different names (trade and generic) and some names are quite long to be written on a label. European Union has classified food additives into different groups and given a unique number for its identification, which is called an E-number. A range of E-numbers are given for the following categories of food additives.

E100-E199	Colours
E200-E299	Preservatives
E300-E399	Antioxidants, Acidity regulators
E400-E499	Thickeners, Stabilisers, Emulsifiers
E500-E599	Acidity regulators, Anti-caking agents
E600-E699	Flavour enhancers
E700-E799	Antibiotics
E900-E999	Miscellaneous
E1000-E1599	Additional chemicals

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For example, a preservative has an E-number between 200 and 299. This grouping system was initiated in Europe to regulate these food additives and also to inform consumers about E-numbers of the approved food additives. "E-numbers" are used in Europe for all approved additives but some countries (*e.g.* Australia and New Zealand) use the **international numbering system** (INS) without the letter "E". Generally, INS-numbers and E-numbers are the same for a given compound (*e.g*. The E-number and INS-number of Tartrazine is E-102 and 102, respectively). INS-numbers are not unique and one number may be assigned to a group of similar compounds. INS identifies all additives, regardless of whether they are approved or not. Some selected food additives and their INS-numbers are listed in the Appendix-II; page 15.

Q: Write the E-numbers of (i) benzoic acid, (ii) ascorbic acid, (iii) citric acid, (iv) potassium gluconate and (v) monosodium glutamate.

A: (i) E-210 (ii) E-300 (iii) E-330 (iv) E-577
(v) E-621
(You don't have to remember E-numbers for examination purposes)

You may be allergic to certain types of food additives. If you have some idea of their E-numbers you should be able to avoid buying food products containing such allergic substances. As we all like sweets let us learn about sweeteners and their E-numbers.

2. Sweeteners

Natural sugars are an important class of food additives that give *sweetness and energy*. Table sugar obtained from sugar cane is a sweet-tasting carbohydrate called s*ucrose*. As you know, it is a disaccharide made up from *glucose* and *fructose*. However, excessive use of sugar is associated with a few health problems including tooth decay, obesity and diabetes. Alternative *non-calorie* artificial sweeteners have therefore been developed which provide only the sweetness. Artificial sweeteners are divided into two categories:

(i) intense sweeteners and
(ii) bulk sweeteners.

2.1 Intense sweeteners

These are much sweeter than sugar and are therefore typically used in *small quantities* to replace the sweetness of sugars. They provide virtually *no calories*. Saccharin, aspartame, cyclamate, acesulfame-K, sucralose, alitame are the common intense sweeteners, (see Figure 1 for molecular structures and Table 1 for their E-numbers and sweetness values with respect to sucrose).

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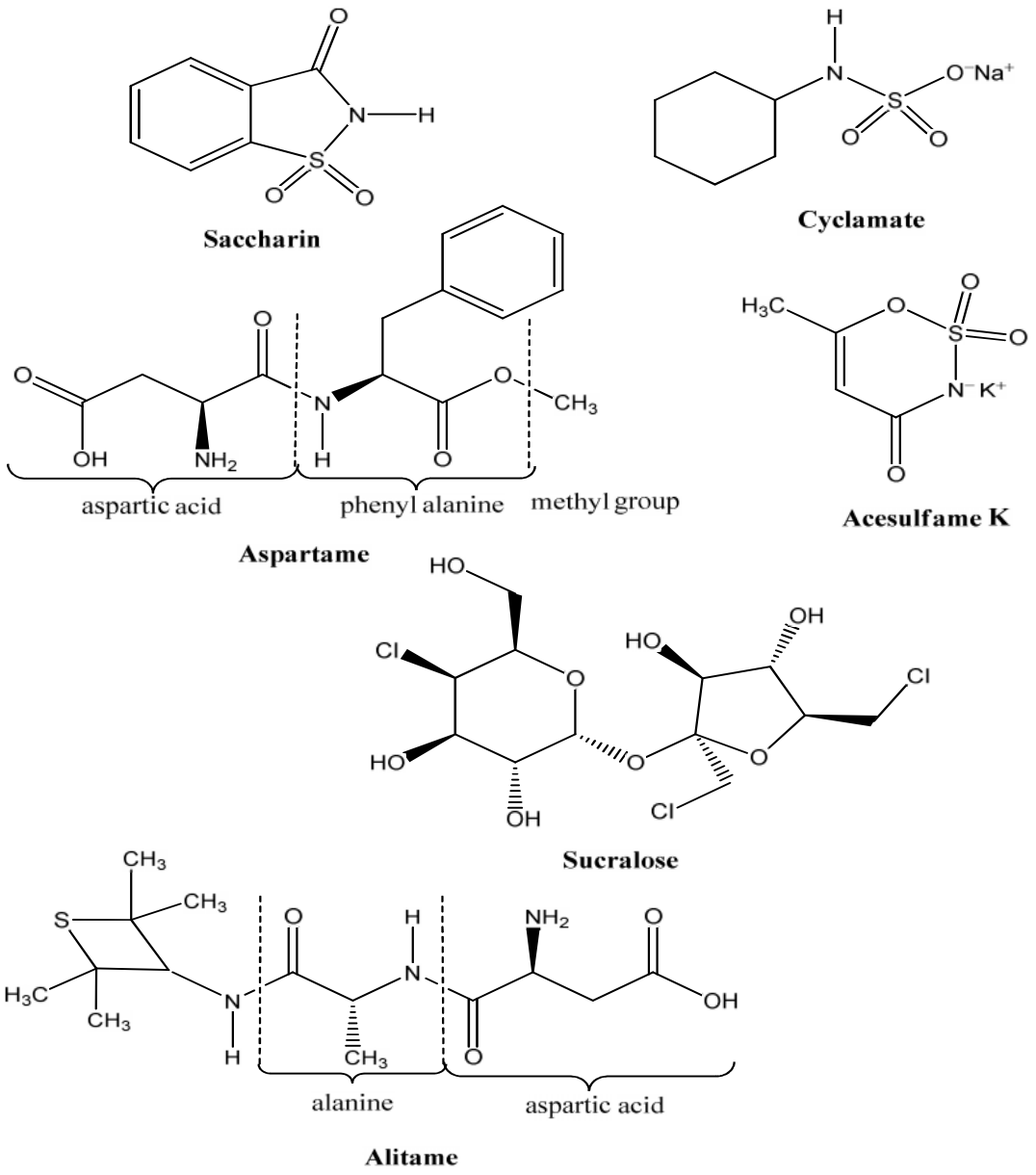

Figure 1 *Some common intense sweeteners (▬ and ┈┈ indicates the chirality/stereochemistry at carbon centres)*

Table 1 Some intense sweeteners, their E-numbers and sweetness values

Sweetener	E-number	Sweetness per sucrose
Saccharin	954	300
Aspartame	951	200
Cyclamate	952	30-50
Acesulfame K	950	200
Sucralose	955	600
Alitame	956	2000

Saccharin (2*H*-2-benzothiazol-1,1,3-trione)

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Saccharin was discovered in 1879 by Constantine Fahlberg and is 300 times sweeter than sucrose. It exhibits a *bitter, metallic aftertaste* and this effect becomes more evident with increasing concentration. Saccharin is rapidly absorbed into the body, and then is rapidly excreted with urine.

Cyclamate (Sodium N-cyclohexylsulfamate)

Cyclamate was accidentally discovered in 1937 by graduate student Michael Sveda and tastes much like sucrose without significant interfering taste sensations, and is stable to heat. Its sweetness lasts for a longer period than that of sucrose.

Aspartame (L-aspartyl-L-phenylalanine methyl ester)

Aspartame was discovered in 1965 and is a caloric sweetener because it is a *dipeptide* that is completely digested after consumption. Aspartame is noted for a clean, sweet taste that is similar to that of sucrose and only very small amounts are needed for sweetening purposes. Two disadvantages of aspartame are (i) not stable in acid conditions, and (ii) rapid degradation when exposed to elevated temperatures. As other small peptides, aspartame is susceptible to hydrolysis and microbial degradation.

Acesulfame K (6-methyl-1,2,3-oxathiazine-4(3H)-one-2,2-dioxide)

Acesulfame potassium was accidentally discovered in 1967 by Karl Clauss and exhibits a sweetness values between that of cyclamate and saccharin. Since it possesses some metallic and bitter taste, it is especially useful when blended with other low-calorie sweeteners. Acesulfame K is exceptionally stable at elevated temperatures used in baking, and it is also stable in acid conditions, *e.g*. carbonated soft drinks. It is not metabolised in the body and excreted unchanged, thus it does not provide calories.

Sucralose (1,6-dichloro-1,6-dideoxy-β-fructofuranosyl-4-chloro-α-D galactopyranoside)

Sucralose was discovered in 1976 and is produced by the selective chlorination of sucrose. It exhibits a high degree of crystallinity, high water solubility, and very good stability at high temperatures. It is also quite stable at pH values of carbonated soft drinks. But it could undergo limited hydrolysis to give two monosaccharide units during storage for a longer period. As an exercise draw the Haworth projection of sucralose.

Alitame (L-α-aspartyl-N-(2,2,4,4-tetramethyl-3-thietanyl)-D-alaninamide)

Alitame (brand name Aclame) was developed by Pfizer in 1980 and is an amino acid based sweetener that possesses a sweetness of about 2000 times that of sucrose. It exhibits a sweet taste similar to sucrose. It is very soluble in water with a good thermal stability and a shelf life. However it is prone to change its flavour when stored in acidic solutions for a long time.

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2.2 Bulk sweeteners

Bulk sweeteners are mainly polyols, for example, erythritol (E968), mannitol (E421), sorbitol (E420) and xylitol (E969), which are derivatives of normal sugars (aldoses). They can be obtained by reducing the aldehyde (CHO) group into a (CH_2OH) group. They add sweetness and calories to food and beverages. Some of the bulk sweeteners are given below.

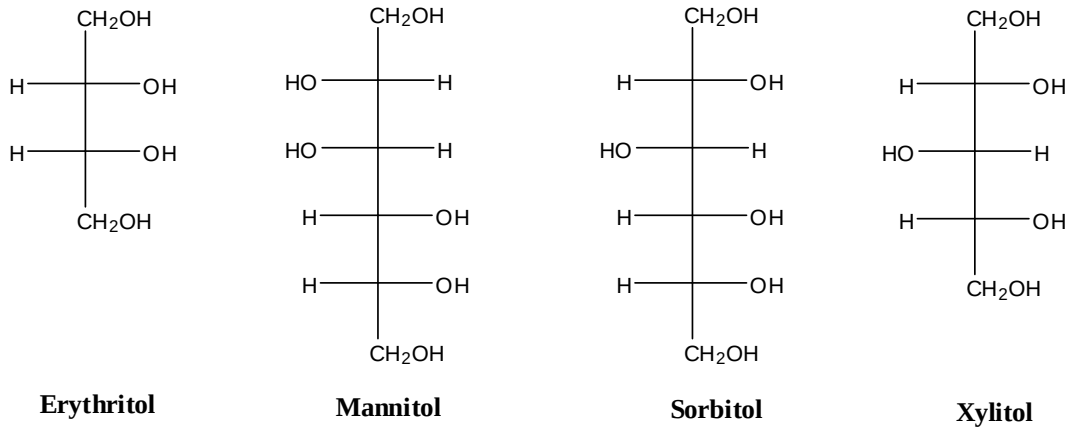

Figure 2 *Bulk sweeteners derived from aldoses*

Q: How would you convert erythrose to erythritol?

A: By reducing it with $LiAlH_4$.

3. Food preservatives

Food preservation can be *defined* as the science which deals with the process of prevention from decay or spoilage of food and helps them to be stored in a fit condition for future use. Food preservation is not a modern day invention but a process that advanced with the transformation of society.

Due to the high demand and the consumption of processed food, artificially manufactured preservatives are widely used in the food industry. Preservatives are also known as antimicrobial agents, because of their action against food-born microbes which are responsible for food spoilage and food poisoning. Not only chemical preservatives, we can add pasteurization, sterilization, refrigeration, freezing, canning and irradiation to the list of present food preservation. Therefore we can define a food preservative as a substance which is capable of inhibiting, retarding or arresting the growth of micro-organisms.

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Traditional methods of food preservation

Let us consider a few traditional methods of food preservation that we have been using in our country for generations.

Sun-drying – In this process, direct solar radiation used for drying food such as vegetables, fruits, fish and shrimp.

Smoking – Food like fish and meat are usually preserved by exposing them to smoke by burning some special kind of wood. Here, the heat from the smoke removes moisture; at the same time exposure to smoke imparts a characteristic flavour to the food.

Salting – Salting is a method of preservation of food such as fish and meat with dry edible salt and it is related to pickling. Pathogenic organism cannot survive in a high salty environment due to the hypertonic nature of salt.

Pickling – Organic acids such as acetic acid (vinegar), citric acid (lime juice) andlactic acid are added to preserve food.

Common food preservatives

Let us look at some chemicals/substances (*e.g.* sulphites, sulphur dioxide, nitrites, nitrate, sorbic acid, benzoic acid and propionic acid) which are used as preservatives in the food industry.

Sulphites and sulphur dioxide (E220-E228)

Sulphur compounds are used in the preparation and/or storage of food and beverages. They function as agents for freshening, preservation, reducing, bleaching and the control of enzymic and non-enzymic browning, and as antioxidants. The common preservatives are SO_2 and sodium, potassium or calcium salts of sulphite, bisulphite or metabisulphite, *e.g*: Na_2SO_3 (E221), $NaHSO_3$ (E222) and $Na_2S_2O_5$ (E223).

Sulphur dioxide is used in a wide range of food products including soup packets, dried bananas and apricots, tinned meat, sausages, beer, wine and jams. Generally SO_2 and its derivatives are metabolized to sulphate and excreted in the urine without any obvious pathologic results. However, it was pointed out that some asthmatics are sensitive to SO_2 and its derivatives. Nonetheless, these preservatives serve key roles in contemporary food.

Nitrites and nitrates (E249-E250)

These curing ingredients are required to achieve the characteristic flavour, colour and stability of cured meat. Nitrates and nitrites are converted to nitric oxide by micro organisms and combine with the meat pigment myoglobin to form nitrosomyoglobin, the pigment responsible for the pink colour of cured meat. Nitrites provide protection against the growth of botulism-producing organisms (*Clostridium botulinum*), retard rancidity and stabilize the flavour of the cured meat.

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Sorbic acid (E200)

Sorbic acid and its sodium and potassium salts are among the most important food preservatives used in industrialised countries over a wide range of food and beverages such as dairy products, fish and seafood, fat based products, fruit and vegetable products, baked food and cookies.

It is particularly effective in preventing mould growth. It gives no taste or flavour to products. The antimycotic (antifungal) action of sorbic acid appears to arise because moulds are unable to metabolize the α-unsaturated diene system of its aliphatic chain. It has been suggested that the diene structure of sorbic acid interferes with cellular dehydrogenation, which is assumed as the first step in oxidation.

Benzoic acid (E210)

Benzoic acid is used in developing countries, particularly, in acidic conditions which include non-alcoholic beverages, products prone to spoilage by bacteria and fruit products. It has been found to cause no harmful effect in humans when used in small amounts. It is readily eliminated from the body primarily by reacting with glycine to form hippuric acid (N-benzoly glycine). This detoxification step precludes accumulation of benzoic acid in the body.

Propionic acid (E280)

The propionates (salts of propionic acid) are naturally occurring preservatives. They work better in the more alkaline conditions of bakery products. The toxicity of propionic acid to moulds and certain organisms is due to the inability of the affected organisms to break down the three carbon skeleton. In mammals, propionic acid is metabolised in a manner similar to that of other fatty acids, and it has not been shown to cause any toxic effect at the recommended level.

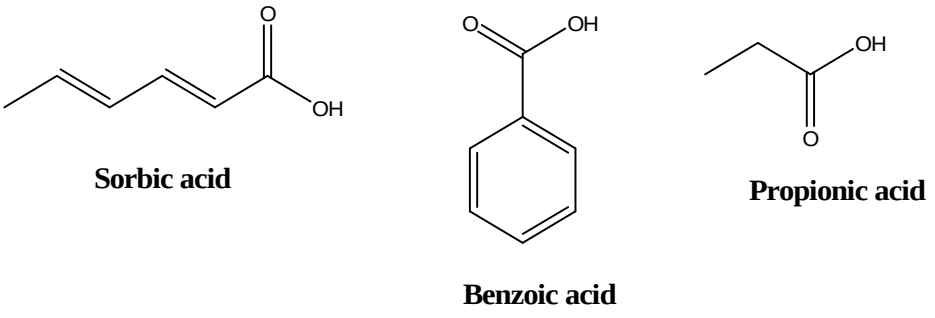

Figure 3 *Structures of preservatives, sorbic acid, propionic acid, and benzoic acid*

4. Antioxidants

Antioxidants are substances which are added to food (such as, margarines, cheese, tinned fruits, crisps, *etc*.) that contain unsaturated fats to prevent them from turning rancid, due to oxidation or chemical reactions. Ascorbic acid, Tocopherols, **b**utylated **h**ydroxy**a**nisole (BHA) and **b**utylated **h**ydroxy**t**oluene (BHT) are some common antioxidants used in the food industry (see Figure 4).

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Ascorbic acid (vitamin C) helps to prevent cut and pulped food from going brown by preventing oxidation that causes the discolouration. It is found in beers, cut-fruits, jams and dried potatoes.

Tocopherols (vitamin E) reduce oxidation of fatty acids and some vitamins.

BHA is found in butter, meats, cereals, chewing gum, backed goods, snack food, dehydrated potatoes and beers. When BHA is present, oxygen reacts preferentially with BHA rather than oxidizing fats or oils, thereby protecting them from becoming rancid. It is also used to preserve food odour, colour and flavour.

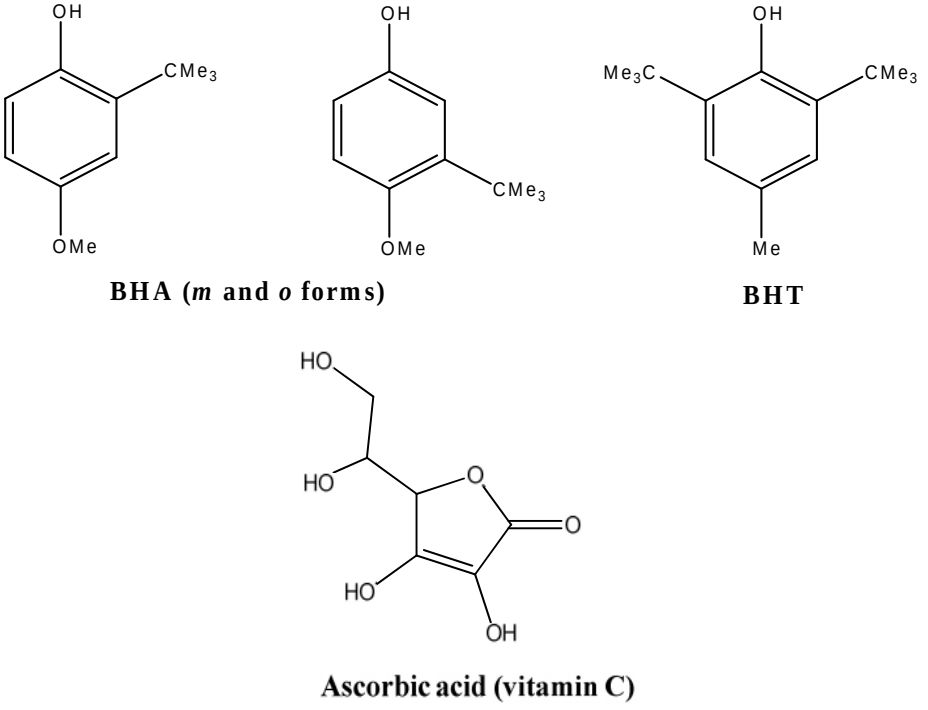

Figure 4 *Structures of antioxidants BHA, BHT and ascorbic acid*

5. Flavours and flavour enhancers

We know that sweet, bitter, salt and sour are the four main tastes we feel. The diagram given below shows the major taste areas of the tongue.

Figure 5 *Figure of a tongue*

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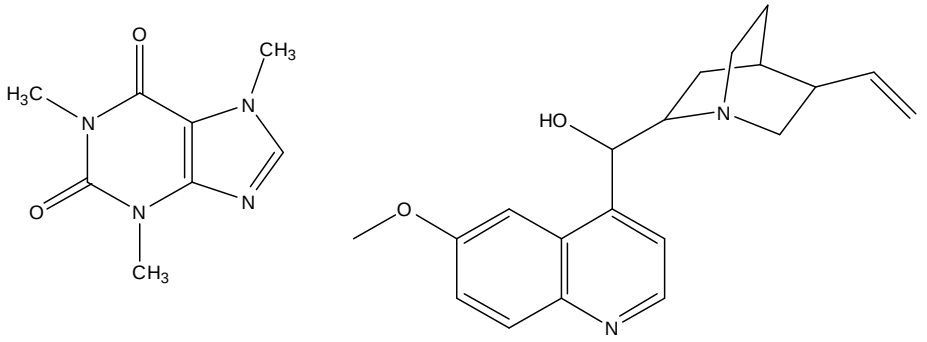
Different people feel the same flavour differently because of genetic differences in humans. For example, saccharin is perceived purely sweet by some individuals but some may find it slightly bitter. Bitter substances have lower taste thresholds than other taste providers (*i.e.* sweet, salt and sour), and bitter substances tend to be less soluble in water than other taste providers. Two examples of bitter substances used in the food industry are caffeine and quinine.



Caffeine **Quinine**

Figure 6 *Molecular structures of caffeine and quinine*

Caffeine occurs in coffee, tea and cola nuts. It is added in concentration up to 200 ppm to soft cola beverages. Quinine is permitted as an additive in soft-drink beverages. Classic salty taste is represented by sodium chloride and is also given by lithium chloride. Chemically, it appears that cations cause salty tastes and anions modify salty tastes. Sodium and lithium produce only tastes, while potassium and other alkaline earth cations produce both salty and bitter tastes. Sour taste is given by the acids present in food like fruits and dairy products, for example citric acid, acetic acid and lactic acid.

Flavour enhancers

Flavour enhancers increase the desirable taste of food when used at levels below their independent detection thresholds. Their effects are prominent and desirable in the flavours of vegetables, dairy products, meat, poultry, fish and other seafood. The best known example is "monosodium glutamate" (MSG). MSG is a sodium salt of the naturally occurring non-essential amino acid, glutamic acid, with the trade names of Ajinomoto, Vetsin and Accent. It was once predominately made from wheat gluten, but is now mostly made from bacterial fermentation. MSG is safer for most people when eaten at customary levels. However, some people may have an MSG intolerance which causes "MSG symptom complex" and a worsening of asthmatic symptoms. MSG may also be associated with migraine headaches, food allergies in children, obesity and hyperactivity in children.

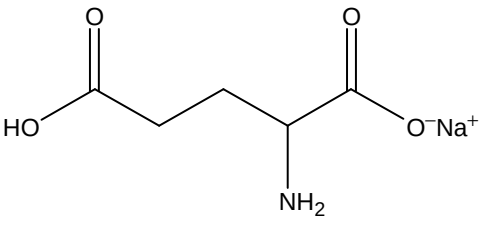


Figure 7 *Structure of MSG*

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6. Spices

Spices are ingredients used to improve the flavour and taste of food and also to make food look more colourful and attractive. In the past, the use of spices by our ancestors in food preparation was to slow the spoilage of food by inhibitory actions of some of the active components present in spices. Spices contain both volatile and non-volatile components. The non-volatiles are responsible for attractive look and the taste of the food. The volatiles of spices (*e.g*. spice oils) are food flavouring agents.

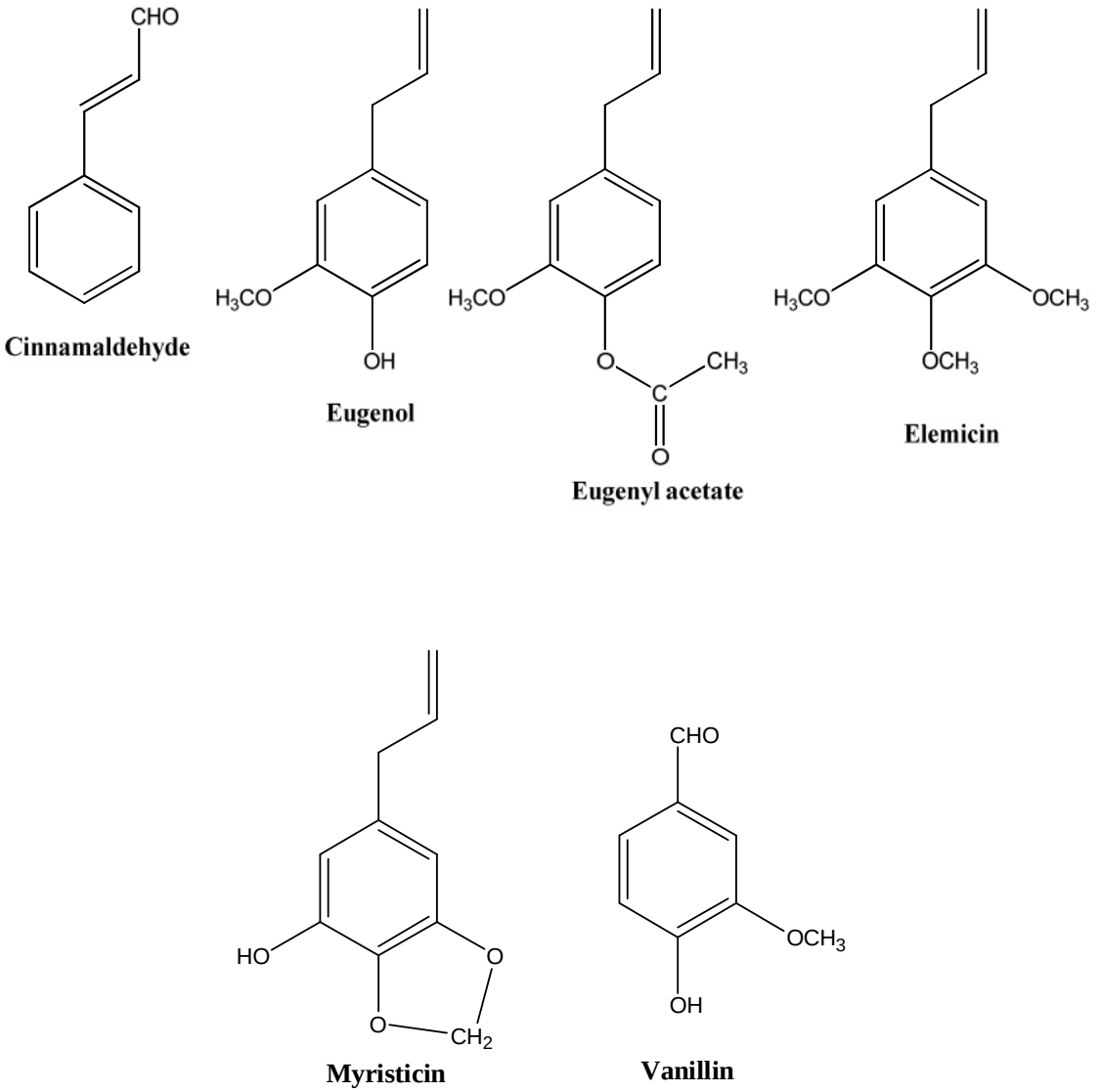

Figure 10 *Structures of a few flavour, colour and pungent components*

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Table 2 gives some common spices with their Sinhala names, their important compounds and uses.

Table 2 Spices, their major components and uses

Spice (Sinhala name)	Plant part	Important flavour, colour and pungent components	Uses
Cardamom (Enasal)	Fruit	α-Terpinylacetate, 1,8-Cineole, Linalool	Gives an aromatic fragrance
Chilli (Miris)	Fruit	Capsaicin	Adds taste, colour and hot sensation to food
Cinnamon (Kurundu)	Bark, leaves	Cinnamaldehyde, Eugenol	Has a pleasant fragrance and destroy toxic substances in food
Clove (Karabu-neti)	Flower bud	Eugenol, Eugenyl acetate	Has a pleasant fragrance and used as an aid to digestion and for toothaches
Coriander (Kottamalli)	Fruit	D-Linalool, 2-Alkenals	Has a pleasant fragrance and destroys toxic substances in food
Ginger (Inguru)	Rhizome	Gingerol, Shagoal, Geranial, Zingerone	Enhances the flavour of food and used as an antidote
Mustard (Abba)	Seed	Allyl isothiocyanate	Enhances the flavour of food
Nutmeg (Saddikka)	Seed	Sabinine, α-Pinene, Myristicin, Elemicin	Improves the flavour of curries and used as an antidote for stomach-aches
Parsley	Leaves, seed	Apiol	Gives a good appearance to food and enhances the flavour
Pepper (Gammiris)	Fruit	Piperine, δ-3-Carene, β-Caryopyllene	Adds taste, colour and hot sensation to food and used as an antidote
Turmeric (Kaha)	Rhizome	Turmerone, Zingiberene, 1,8-Cineol, Curcumin	Adds colour to food and used as a medicine
Vanilla	Fruit, seed	Vanillin, *p*-hydroxybenzyl methyl ether	Gives a characteristic flavour to food

Cinnamon, clove, cardamom, pepper, turmeric *etc*. are condiments found in a Sri Lankan kitchen. Essential oils are obtained by steam distillation of these plant materials, as at high temperatures these oils may undergo decomposition or polymerisation. Essential oils are added to perfumes and cosmetics; used as medicines (wintergreen), insect repellents (margosa oil) and in tooth paste (clove oil).

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Summary

- The food additives can be classified into preservatives, antioxidants, flavours, flavour enhancers, food colourings, sweeteners, vitamins, *etc*.
- Consumption of food additives may have certain health risks. Carcinogenesis, hyperactivity in children, precipitation of allergies, and migraine are some known health risks associated with food additives.
- E-numbers" are used in Europe for all approved additives but some countries use numbers without "E", for example, Australia and New Zealand use the international numbering system.
- Alternative non-calorie artificial sweeteners have been developed which provide the sweetness as natural sugar. Artificial sweeteners are divided into two categories, intense sweeteners and bulk sweeteners. Saccharin, aspartame, cyclamate, acesulfame-K, sucralose and alitame are examples for intense sweeteners.
- Food preservation can be defined as the science which deals with the process of prevention of decay or spoilage of food and helps them to be stored in a fit condition for future use.
- Due to high demand for processed food, artificially manufactured preservatives are used in the food industry. Sulphur dioxide, sulphites, nitrates, nitrites, benzoic acid, and propionic acid are some examples of food preservatives.
- Antioxidants are substances which are added to food that contain unsaturated fats to prevent them from turning rancid, due to oxidation.
- Sweet, bitter, salt and sour are the four main tastes we feel.
- The best known flavour enhancer is “monosodium glutamate” (MSG). Health risks such as migraine headaches, food allergies in children, obesity and hyperactivity in children are associated with it.
- Spices are ingredients used to improve the flavour and taste of food and also to make food look more colourful and attractive. They contain both volatile and non-volatile components.

Learning Outcomes

Once you have finished studying this lesson you should be able to

- describe/define the terms such as food additives, preservatives, antioxidants and spices
- discuss the uses and misuses/health risks of food additives
- list the major categories of E-numbers
- compare and contrast the structural nature of simple artificial sweeteners with that of natural sugar
- describe the importance of using preservatives and the antimicrobial action of main types of preservatives
- explain the action of flavours and flavour enhancers in food stuff by giving examples
- describe the uses of spices in our day-to-day life and identify their important components (flavour, pungent *etc*.)

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Activities

1. Write the E-numbers of

(i) saccharin
(ii) sorbic acid
(iii) sorbitol
(iv) sucralose
(v) sodium benzoate
(vi) glycerin
(vii) glycine
(viii) tartrazine

2. Write a short account on aspartame.
3. What is meant by “food preservation”?
4. Name four major intense sweeteners and their sweetness values with respect to sucrose.
5. Give three names of bulk sweeteners.
6. Draw the structures of saccharin, cyclamate and erythritol.
7. Give four methods used for the preservation of food in ancient Sri Lanka.
8. What are antioxidants? Give two examples of antioxidants.
9. What is meant by pickling? Give three examples of pickling agents.
10. Give a brief account on antioxidants.
11. What are spices? Give five examples of them with their uses.

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Answer guide to activities

1. (i) E954 (ii) E200 (iii) E421 (iv) E955
   (v) E211 (vi) E422 (vii) E640 (viii) E102

2 Refer section 2.1

3. Food preservation is prevention of food from decaying or spoiling and to help them to be stored in good condition for future use.

4. Alitame (2000), sucralose (600), saccharin (300) and aspartame (200)

5. Erythritol, mannitol, sorbitol and xylitol (any three), see figure 2.

6. See Figure 1

7. Sun drying, smoking, salting and pickling

8. Antioxidants are added to food containing unsaturated fat to prevent them from turning rancid due to oxidation, *e.g*. BHA, BHT, vitamins C and E.

9. Pickling is preservation of food such as fruits, vegetables by adding organic acids. For example, vinegar, lime juice and lactic acid

10. Refer section 4

11. Spices are ingredients used to improve the flavour and taste of food and also to make food look more colourful and attractive. For examples, refer Table 2.

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Study Questions

1. What is meant by “E-numbers”? What is the importance of having E-numbers?
2. Define the term “food additive”. What are the different types of food additives?
3. What is the range of E-numbers given for food preservatives?
4. What are the four types of flavours?
5. What are the health risks that could be caused by consuming food additives?
6. Draw the structures of cinnamaldehyde, vanillin and eugenol.
7. Write a short account on food preservatives.
8. Give a brief account on essential oils.
9. What are the structural features of eugenol, myristicin and elemicin?
10. Which spices contain eugenol?

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Appendix-II

INS (or E) numbers of some food additives

A = Australia; E = Europe; U = United States

INS number	Approval	Names	Type
100	A E U	Turmeric, curcumin	Colour (yellow and orange)
102	A E	Tartrazine	Colour (yellow and orange) (FDA:FD&C yellow #5)
171	A E	Titanium dioxide	Colour (white)
210	E	Benzoic acid	Preservative
211	A E	Sodium benzoate	Preservative
212	A E	Potassium benzoate	Preservative
220	A E	Sulfur dioxide	Preservative, antioxidant
250	A E	Sodium nitrite	Preservative, colour fixative
260	A E	Glacial acetic acid	Preservative, acidity regulator
270	A E	Lactic acid	Acidity regulator, preservative, antioxidant
300	A E	Ascorbic acid	Antioxidant (water soluble)
325	A E	Sodium lactate	Food acid
330	A E	Citric acid	Food acid
343	A E	Magnesium phosphate	Mineral salt, anti-caking agent
354	A E	Calcium tartrate	Food acid, emulsifier
422	A E	Glycerine	Humectant, sweetener
473	A E	Sucrose esters of fatty acids	Emulsifier
501	A E	Potassium carbonate, potassium bicarbonate	Mineral salt
551	A E	Silicon dioxide	Anti-caking agent
577	A E	Potassium gluconate	Stabilizer
621	A E	Monosodium glutamate (MSG)	Flavour enhancer
623	A E	Calcium diglutamate	Flavour enhancer
640	A E	Glycine	Flavour enhancer
905	A E	Paraffins	Glazing agent
920	A E	L-cysteine	Flour treatment agent
942	A E	Nitrous oxide	Propellant
955	A	Sucralose	Artificial sweetener
1100	A	Amylases	Flour treatment agent
1102	A	Glucose oxidase	Antioxidant
1401	A	Acid treated starch	Thickener, vegetable gum
1420	A E	Acetylated starch	Thickener, vegetable gum
1520	A E	Propylene glycol	Humectant

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