Chemical additives in standardized food

Legislation

Food & Beverages Code

For all additives, please know the following:

- **Definition**
- **1-2 Examples of Compounds**
- **Mode of Action**

Chemical additives



Chemical additives:




«Substances added to food for the purpose of preserving flavor, taste, appearance, and shelf life»

- **synthetic or of natural origin**
- **For example, vinegar & salt: their use has been known for centuries**

Numbering:

- For the convenience of legislation and public information: international number E
  (Codex Alimentarius, 1963, FDA & FAO)

- Outside Europe, the prefix E is usually omitted.

- In America, substances approved for use in food are characterized as 'Generally recognized as safe' or"GRAS" (FDA)

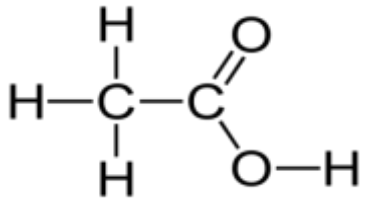
The main categories of chemical additives in standardized food



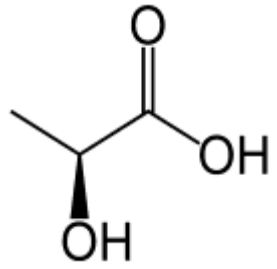

1. Acids - Acidulants

«Substances that increase the acidity of food and/or impart sour taste»

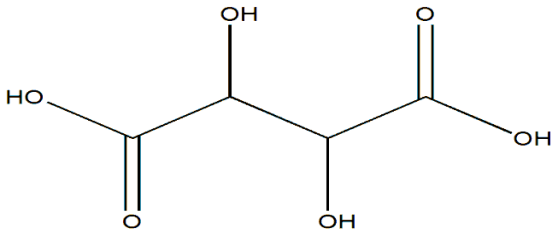
- They provide a 'sour' and 'intense' flavor
- They function as both preservatives and antioxidants



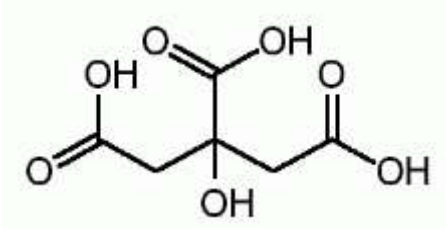
CH_3COOH
Oxalic acid



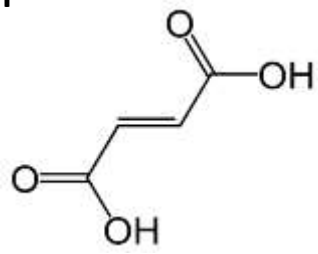
CH_3-CH(OH)-COOH
Lactic acid



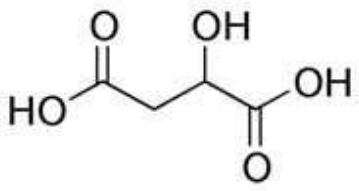
HOOC-CH(OH)-CH(OH)-COOH
Acetic acid.



HOOC-CH_2-C(COOH)(OH)-CH_2-COOH
Citric acid



HOOC-CH=CH-COOH
Fumaric acid



HOOC-CH_2-CH(OH)-COOH
Malic acid

2. Acidity regulators

«Substances that alter or control the acidity or alkalinity of food»

- **organic or inorganic acids**
- **alkalis**
- **compounds with buffering capacity**

For example, citric acid, oxalic acid, and lactic acid

3. Anticaking agents

«Substances that reduce the tendency of individual food particles to adhere to each other»

- **They are commonly used in powdered or granulated food products such as milk powder, tea, coffee, sugar, salt, etc. Examples include:**

✓ **Ca & Mg phosphates**

✓ **Na, K, Ca, Mg, Al, Zn pyrophosphates**

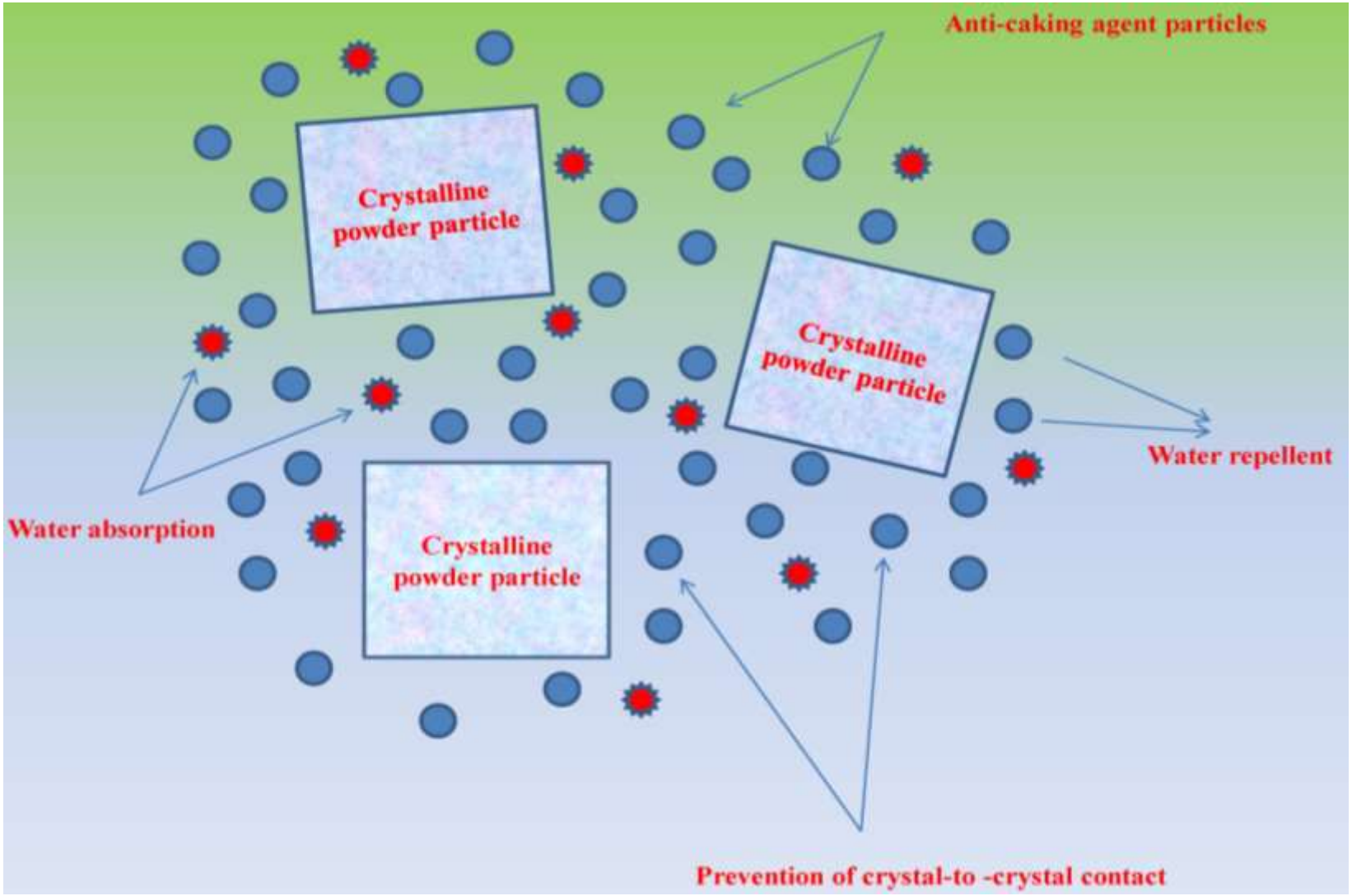
✓ **Talc, kaolin, bentonite**

✓ **Na, Ca, K, Mg salts of fatty acids (which are also used as emulsifiers)**

✓ **Magnesium oxide**

✓ **K, Ca, Na ferrocyanides**

3. Anticaking agents

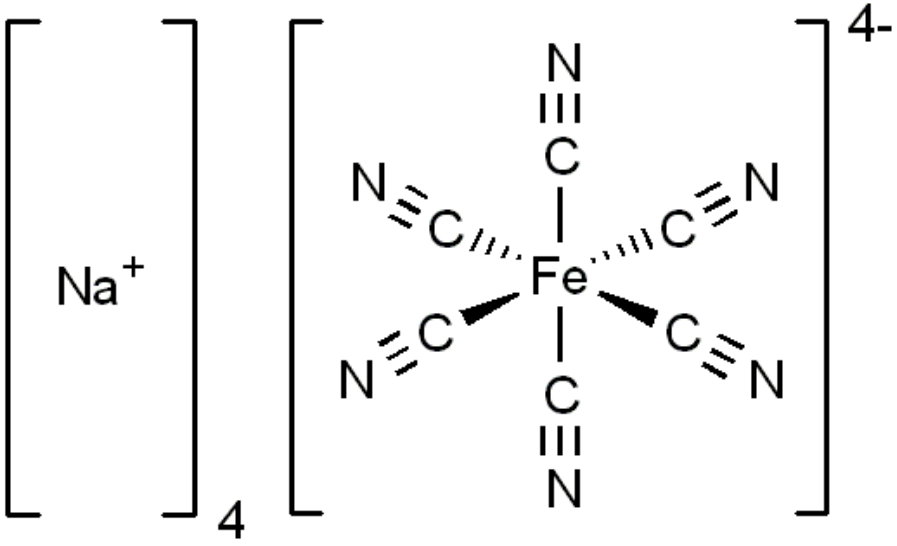


(mode of action)

https://www.mdpi.com/2304-8158/12/1/171

3. Anticaking agents

For example sodium ferrocyanide



- Chemical formula: $Na_4Fe(CN)_6$ & $Na_4Fe(CN)_6 \bullet 10H_2O$ (Na hexacyanoferrate or Yellow Prussiate of Soda-YPS)
- Non-toxic compound
- But in under acidic conditions or in the presence of light, it can decompose and release hydrogen cyanide (HCN)

3. Anticaking agents

Sodium ferrocyanide in salt (NaCl)

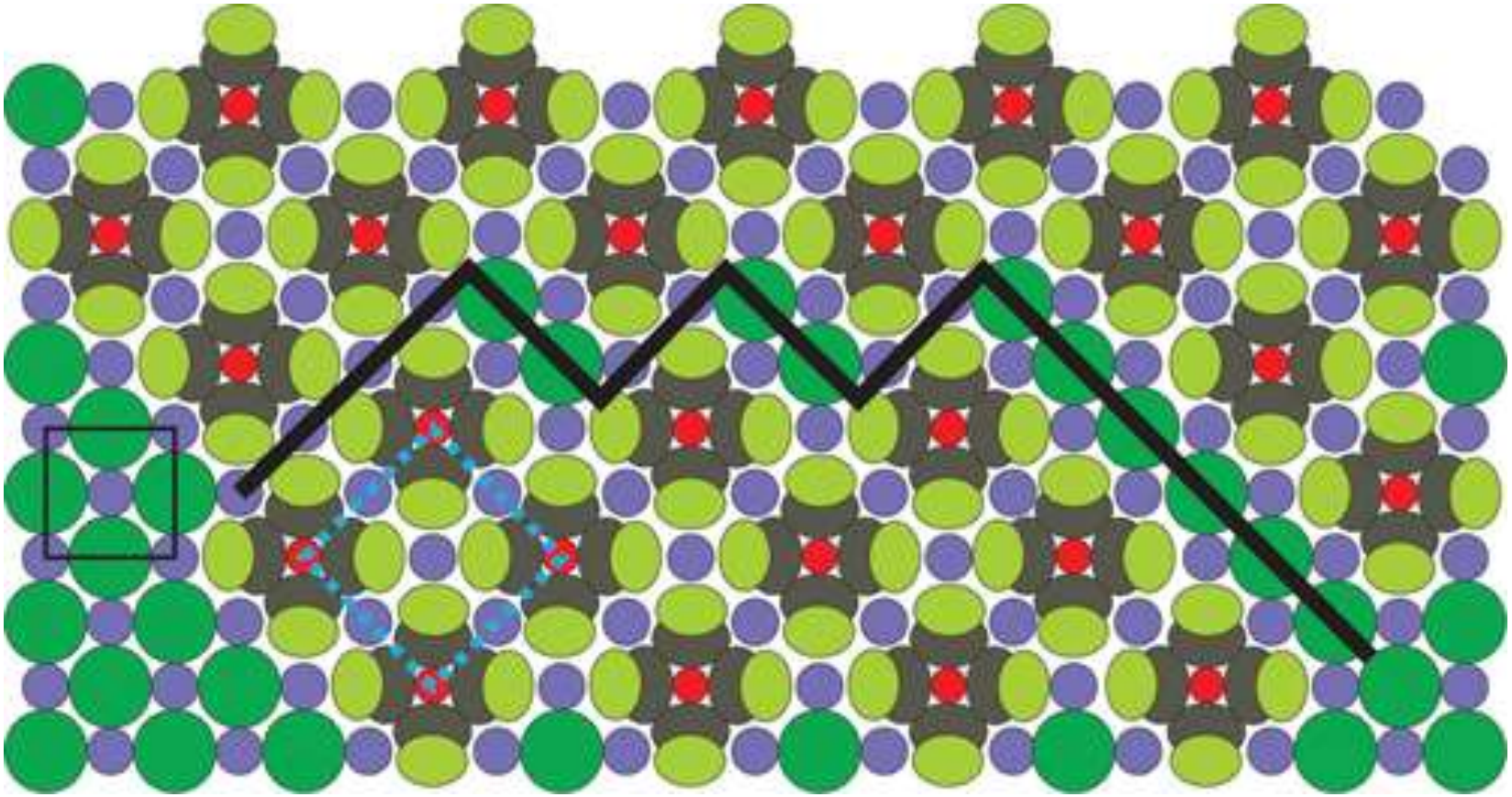
Possible Mechanism*(Bode et al., Cryst. Growth Des. 2012, 12, 4, 1919–1924:*

- NaCl crystals have a strong tendency to agglomerate.
- Through XRD analysis, it was found that a $Fe(CN)_6^{-4}$ ion is adsorbed on the surface of the NaCl crystal, replacing one Na^+ ion and five surrounding Cl^- ions.
- The coverage is approximately 50%.
- Due to the charge of the absorbed $Fe(CN)_6^{-4}$ ions on the surface of NaCl, the crystal can only continue to grow from an energetically unfavorable Na^+ position or by releasing a $Fe(CN)_6^{-4}$ ion.
- Therefore, $Fe(CN)_6^{-4}$ effectively inhibits further growth of NaCl crystals, preventing them from forming agglomerates.

3. Anticaking agents

Sodium ferrocyanide in salt (NaCl)

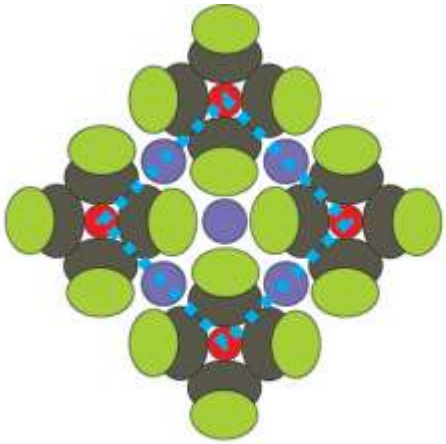
Possible Mechanism*(Bode et al., Cryst. Growth Des. 2012, 12, 4, 1919–1924:*



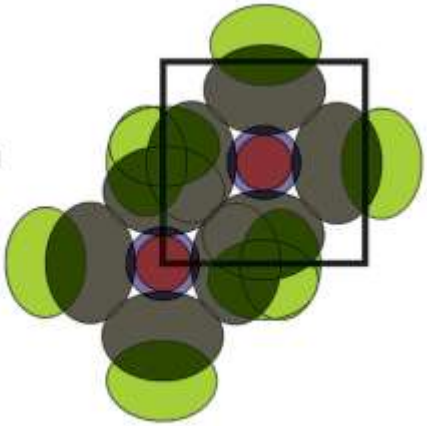
3. Anticaking agents

Sodium ferrocyanide in salt (NaCl)

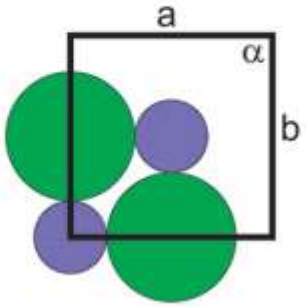
Possible Mechanism *(Bode et al., Cryst. Growth Des. 2012, 12, 4, 1919–1924:*

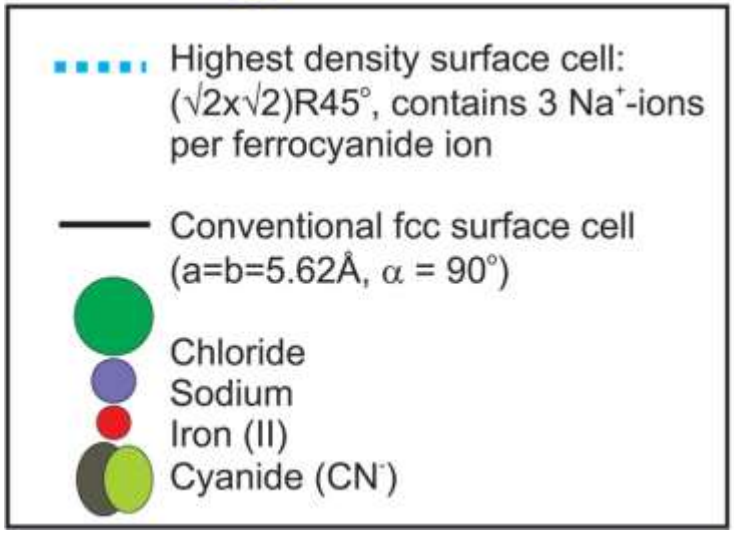


projection on conventional fcc-cell, - ordering =



+ superimposed: sodium chloride cell for clean parts of the surface:

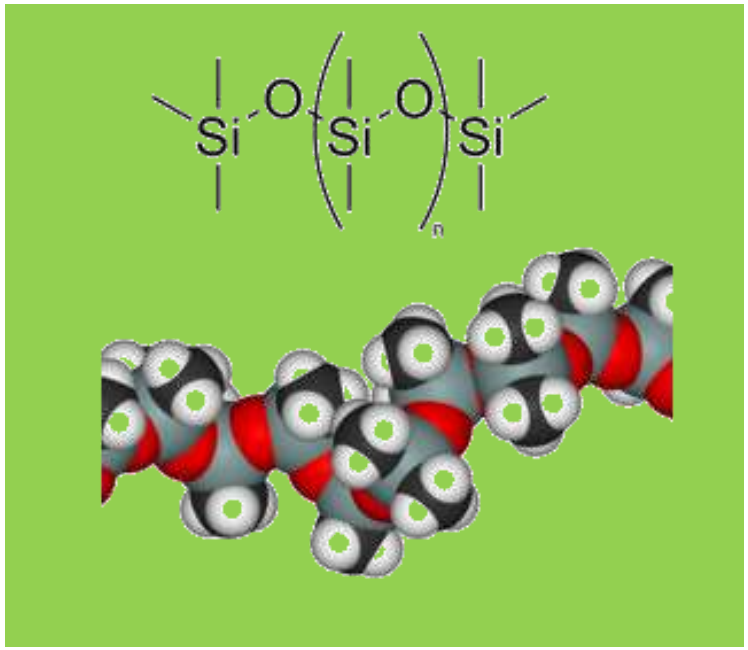




4. Antifoaming agents

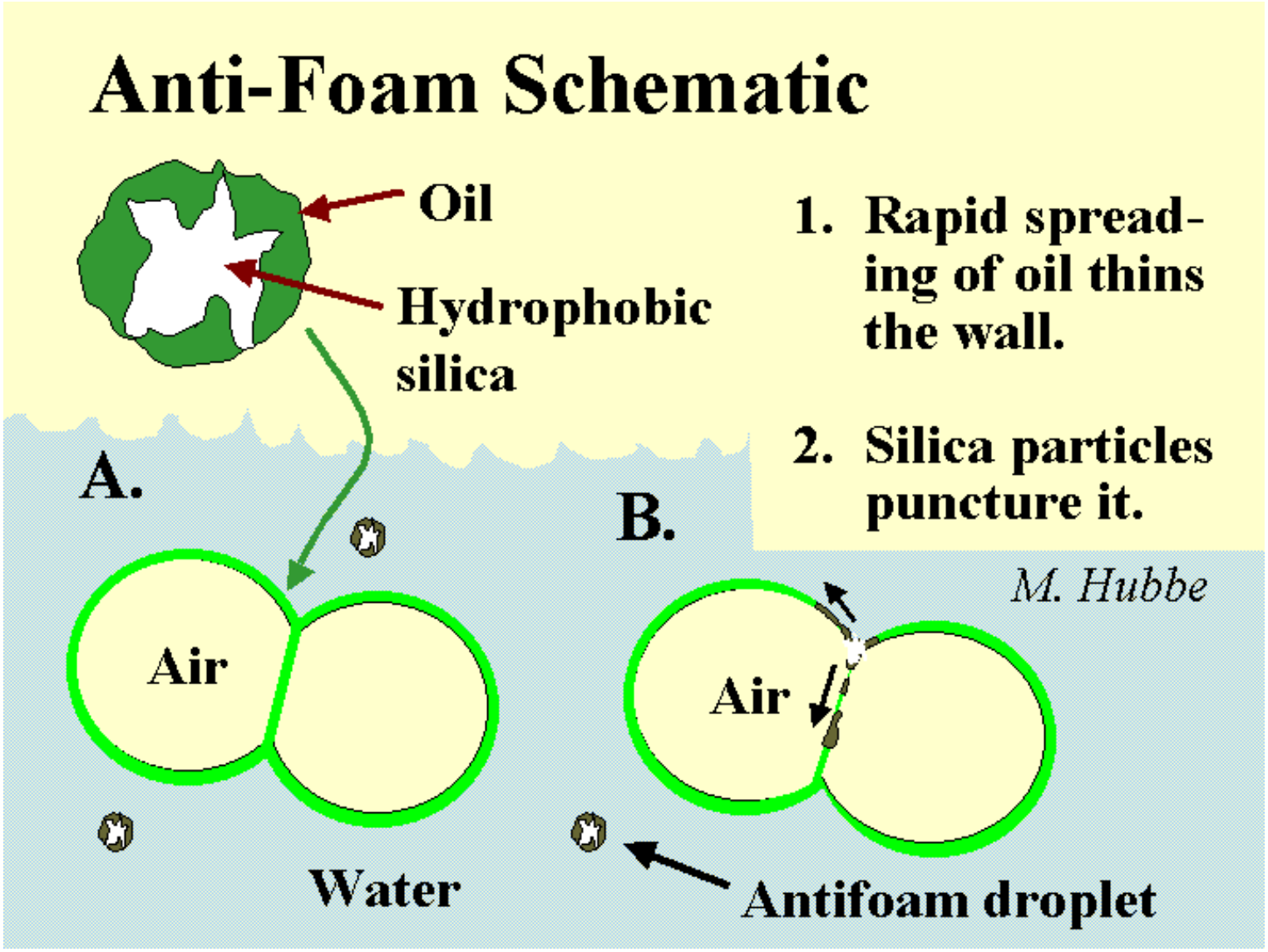
"Substances that prevent or limit foam formation'"

- **Applications: Soft drinks, Frying oils, etc.**

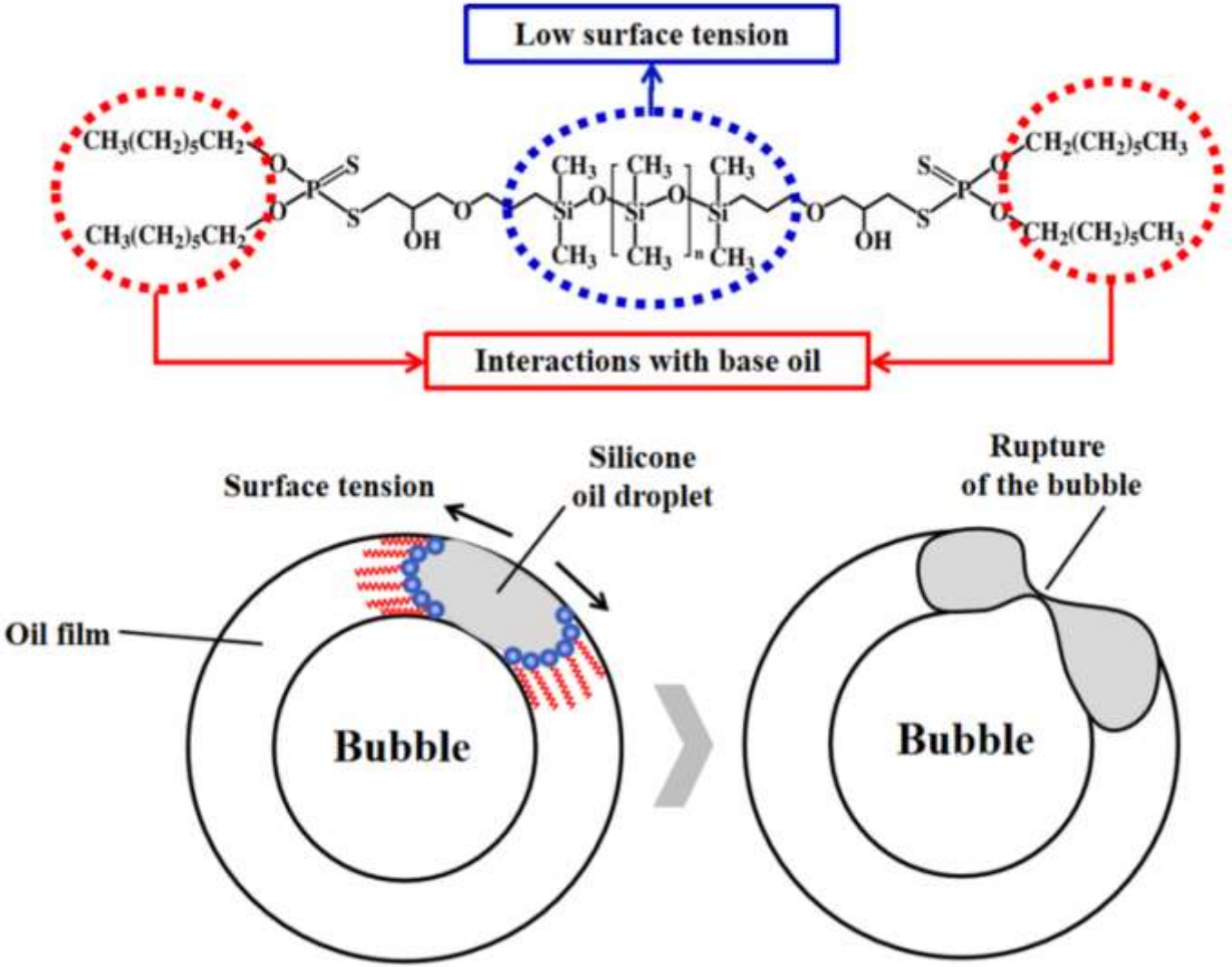


Dimethyl polysiloxane - silicone oil

4. Antifoaming agents



4. Antifoaming agents



Antifoaming mechanism of chemically modified silicone oil (**dioctyl dithiophosphate-terminated silicone oil**)
(Luan et al., 2022; https://doi.org/10.3390/lubricants10120364)

5. Bulking agents

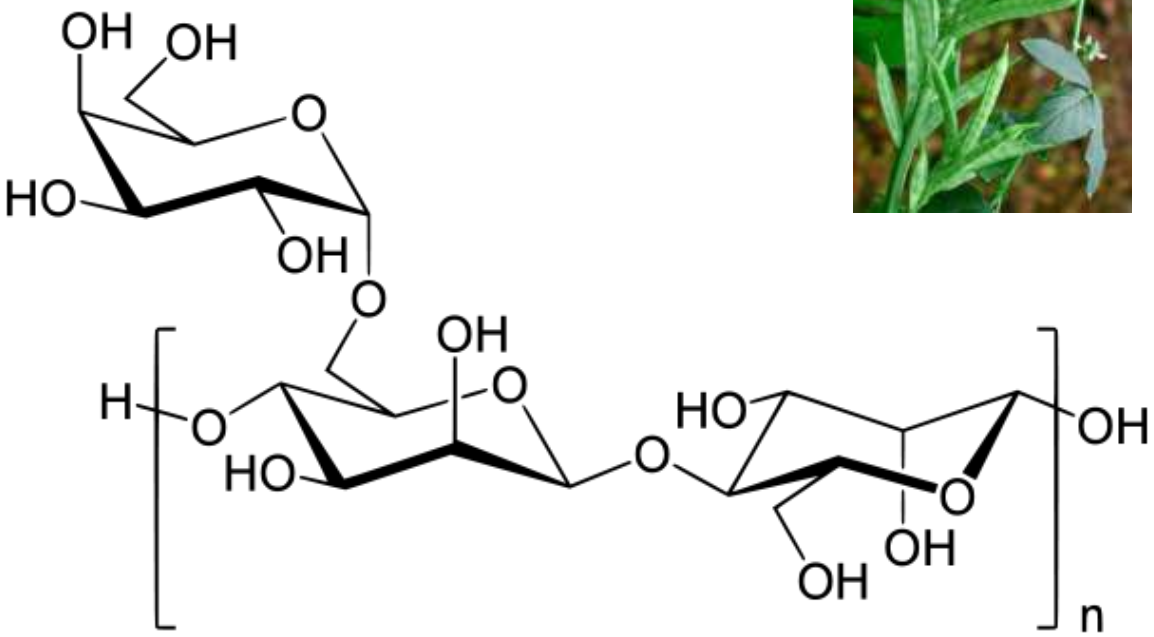
«Substances that contribute to the increase of the volume or weight of food without significantly adding to its caloric value»

- **Applications: meat substitutes, low-calorie foods, confectionery and bakery products, and most standardized foods**
  - ✓ **Guar gum**
  - ✓ **Carnauba wax**
  - ✓ **Mannitol**
  - ✓ **Maltitol**
  - ✓ **Glycerol**
  - ✓ **Methyl cellulose**
  - ✓ **Polydextrose**
  - ✓ **Pectin**
  - ✓ **etc.**

5. Bulking agents

guar gum (Galactomannan):

linear chain of β-1,4-linked mannose monomers with α 1,6-galactose branches every 2 mannose units

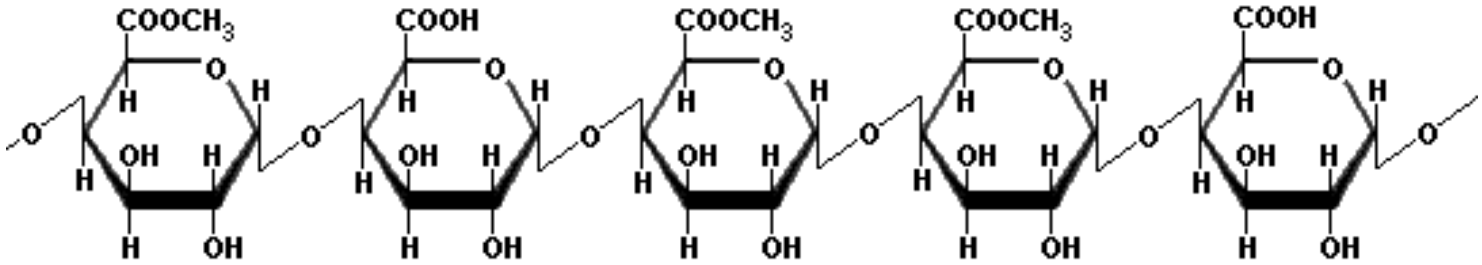


Guaran unit

https://en.wikipedia.org/wiki/Guar_gum

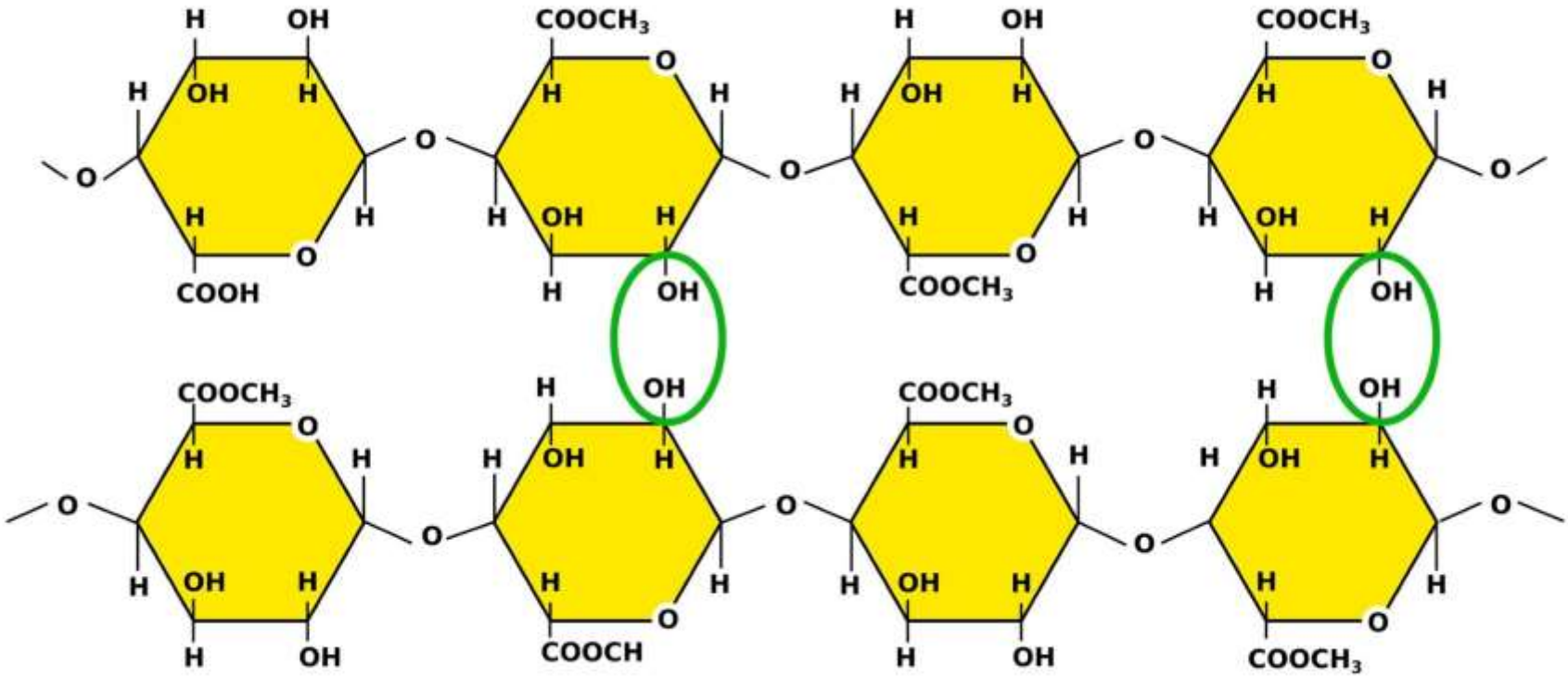
5. Bulking agents

Pectin - polymer of α-galacturonic acid & its methyl esters (partially esterified with methanol)



5. Bulking agents

Pectin gel formation mechanism



Pectin with a high degree of esterification (high-methoxyl pectin; HM pectin)
→ Forms intra-molecular H-bonds

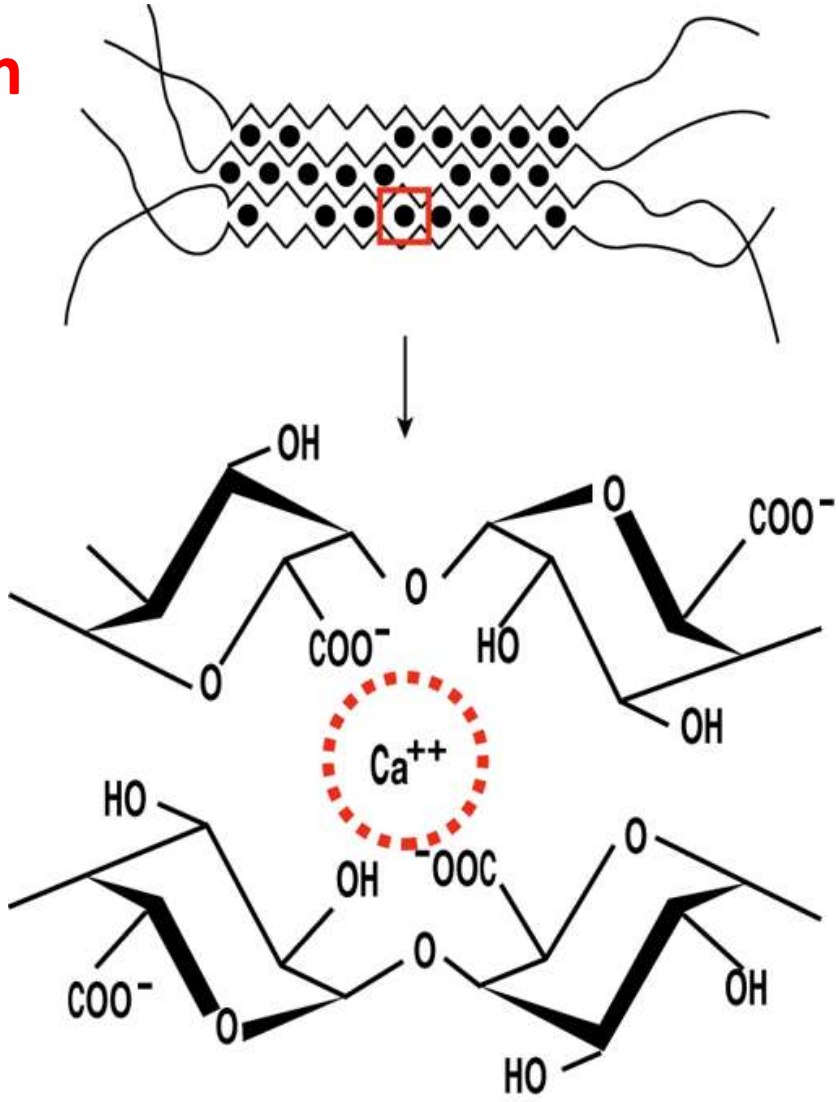
(https://www.silvateam.com/en/products-and-services/food-ingredients/pectin/what-pectin.html)

5. Bulking agents

Pectin gel formation mechanism

Pectin with a low degree of esterification (low-methoxyl pectin; LM pectin)

→ Forms intra-molecular H-bonds, as well as cross-linking with divalent cations, mainly Ca^{2+}, following the "Egg Box" model:



(https://unipektin.ch/wp-content/uploads/2020/05/UPI-Pectin-brochure.-final-version.pdf)

6. Emulsifiers

"Substances that allow the formation or maintenance of a homogeneous mixture of two or more immiscible phases, such as oil in water"

- ✓ **Salts of fatty acids with Al, Ca, Na, Mg, K & NH_4**
- ✓ **Diphosphate, triphosphate, and polyphosphate salts**
- ✓ **Sorbitans: Monostearate, Tristearate, Monooleate, Trioleate, Monopalmitate, Monolaurate**
- ✓ **Polysorbates: Monostearate (p.60), Tristearate (p.65), Monooleate (p.80), Monopalmitate (p.40), Monolaurate (p.20)**

6. Emulsifiers

- ✓ Oxalic, lactic, citric, and tartaric esters of mono- and diglycerides of fatty acids
- ✓ Esters of fatty acids with sucrose
- ✓ Saccharoglycerides
- ✓ Beta-cyclodextrin
- ✓ Cellulose, methyl-, ethyl-, hydroxypropyl-, ethylhydroxyethyl-, carboxymethyl-cellulose, hemicelluloses
- ✓ Various gums
- ✓ Peptides
- ✓ 1,2-Propanediol and its esters with fatty acids

6. Emulsifiers

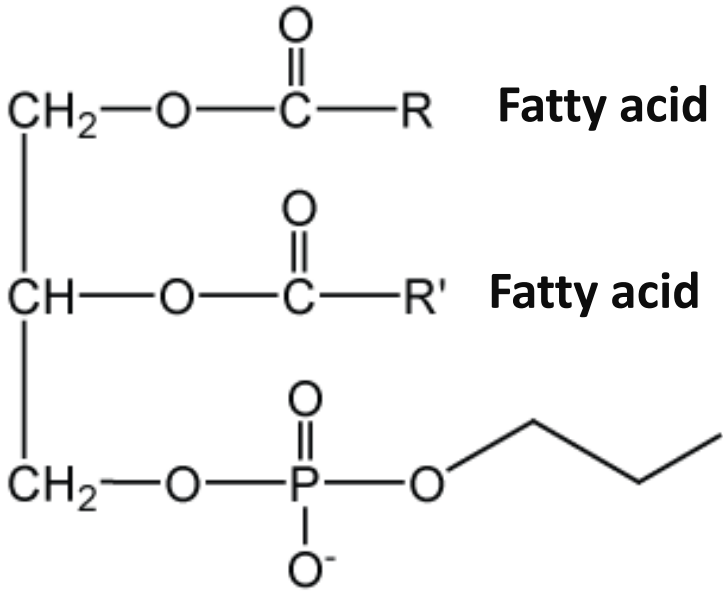
The oldest emulsifier is Egg yolk

Its main emulsifying substance is lecithin, which is a mixture of fatty substances composed of:

- **Phosphoric acid**
- **Choline**
- **Glycerides**
- **Phospholipids such as phosphatidylcholine, phosphatidylethanolamine, and phosphatidylinositol**

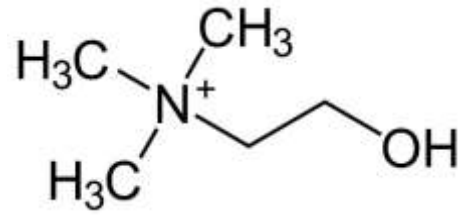
6. Emulsifiers

lecithin

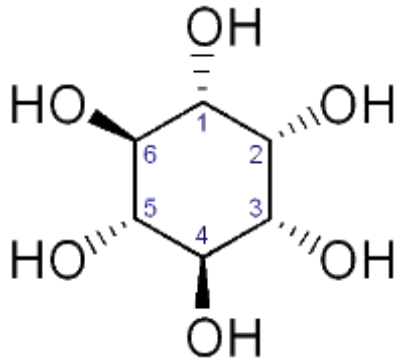


Phospholipid

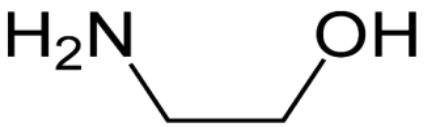
X = Choline, ethanolamine or inositol



Choline



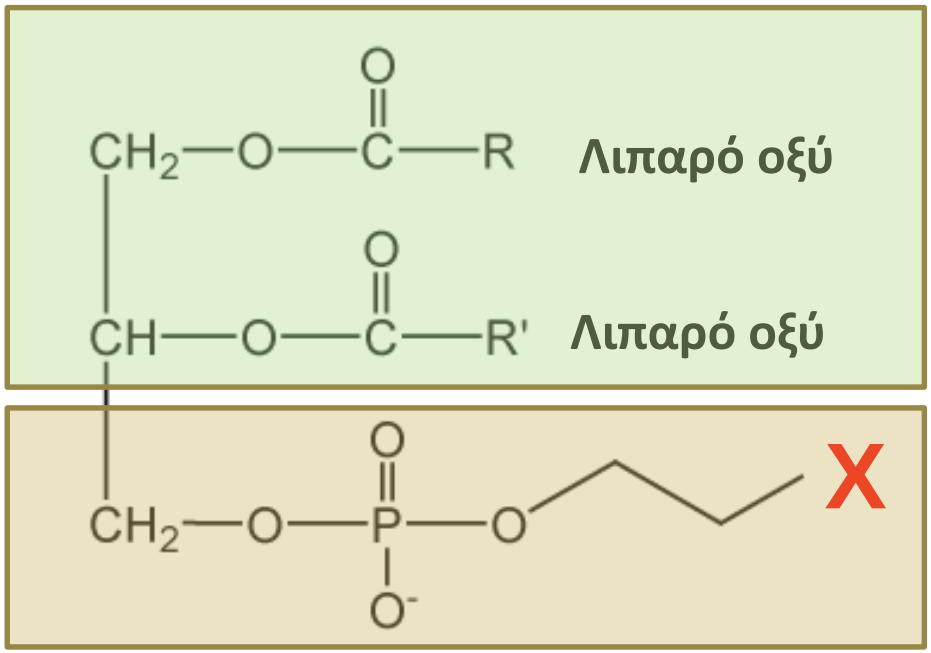
Inositol



Ethanolamine

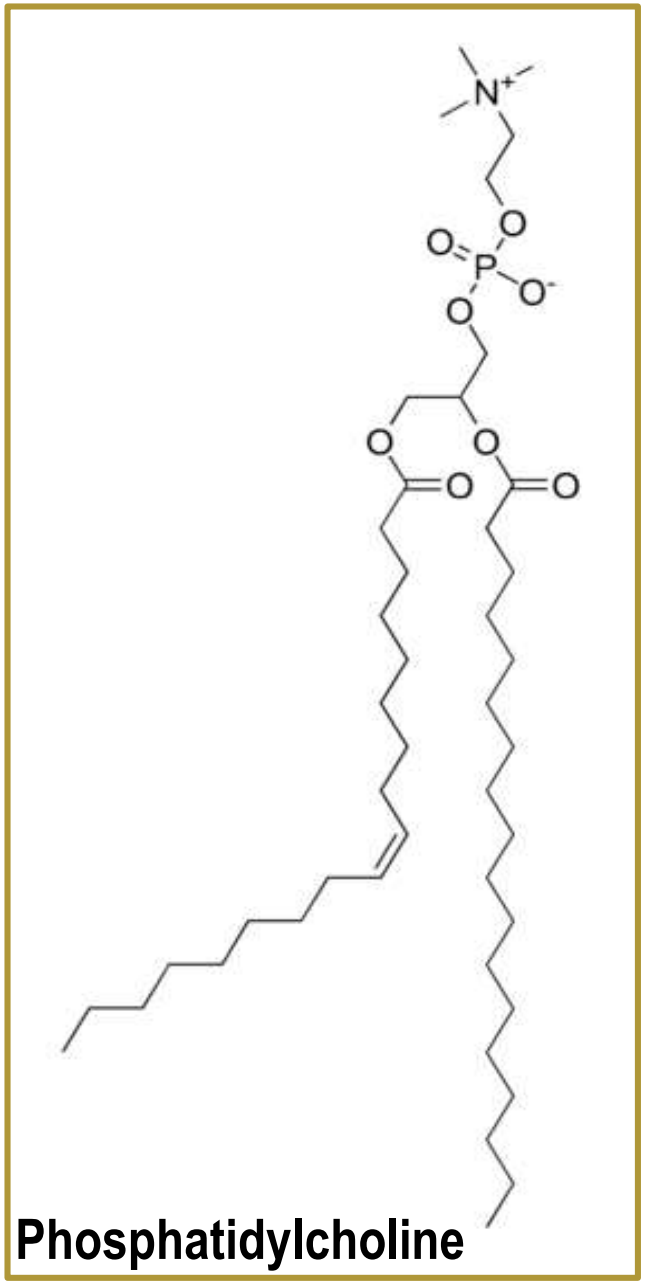
6. Emulsifiers

lecithin

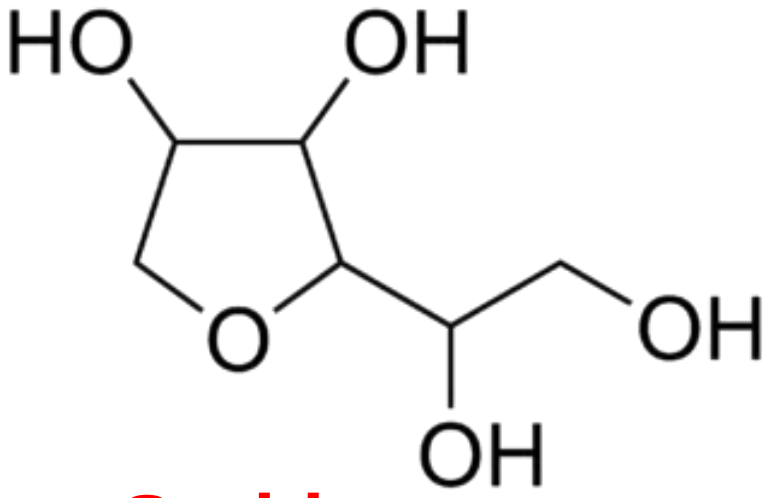


Hydrophobic region

Hydrophilic region



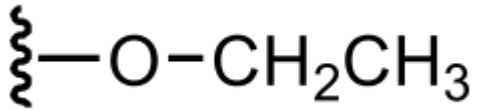
6. Emulsifiers



Sorbitan

Polysorbates

✓Oily liquids derived from ethoxylated sorbitan (a derivative of sorbitol), esterified with fatty acids

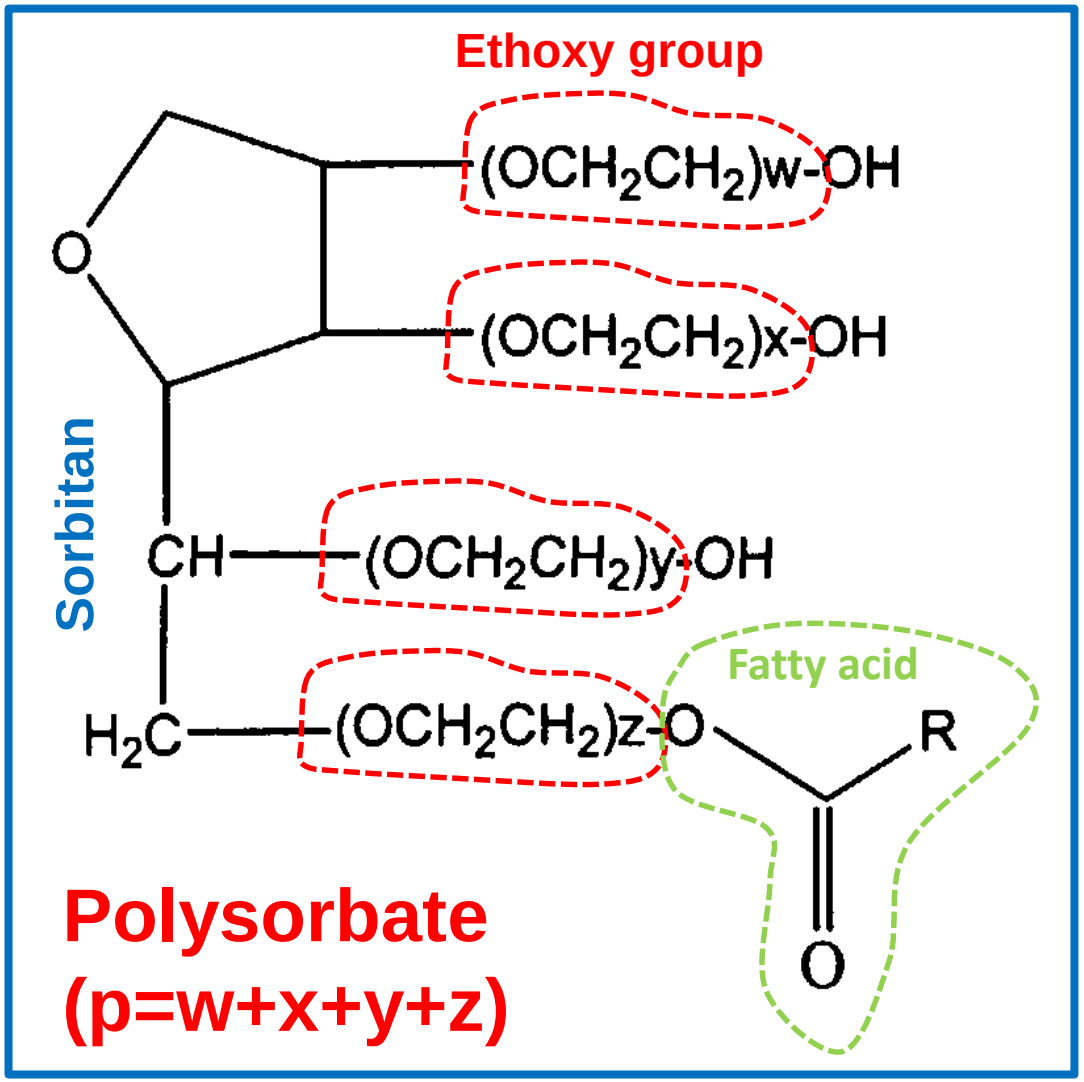


Ethoxy group

6. Emulsifiers

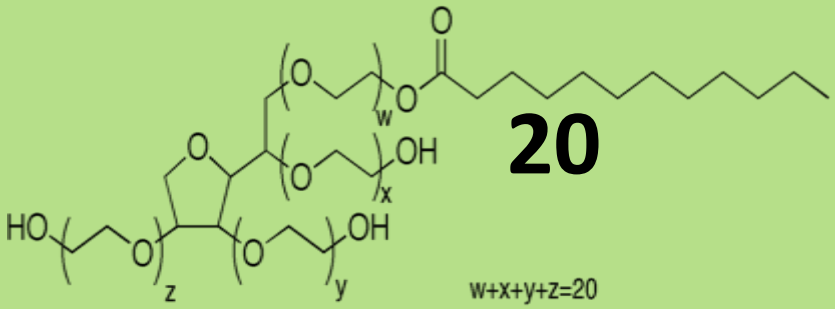
Polysorbates

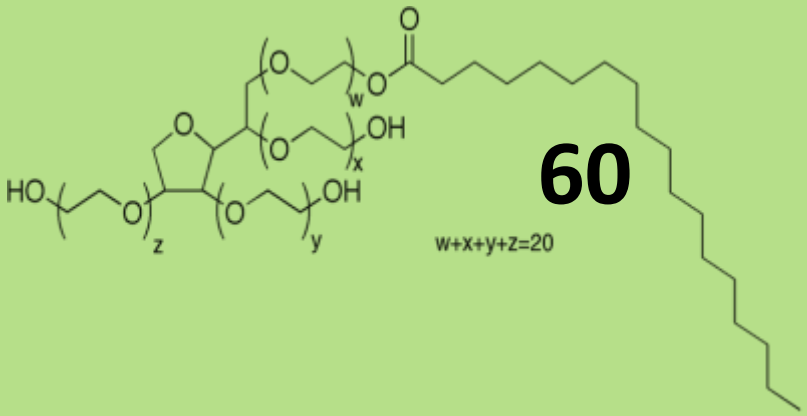
- ✓Monostearate (p.60)
- ✓Tristearate (p.65)
- ✓Monooleate (p.80)
- ✓Monopalmitate (p.40)
- ✓Monolaurate (p.20)

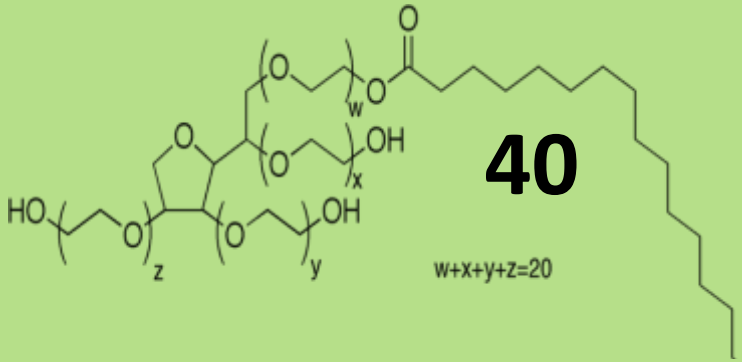


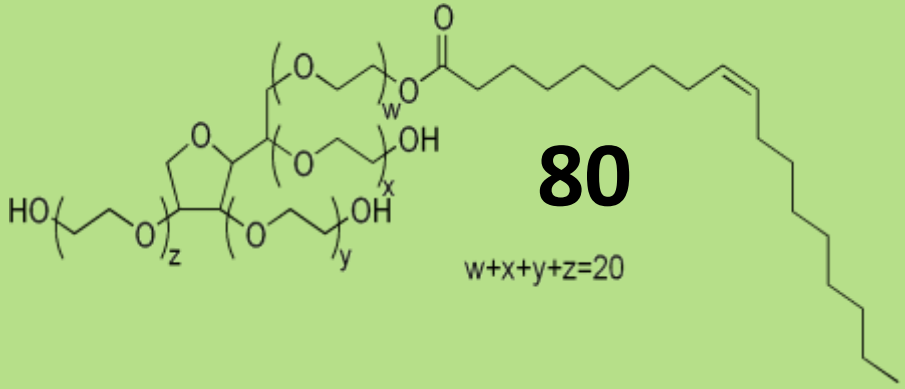
6. Emulsifiers

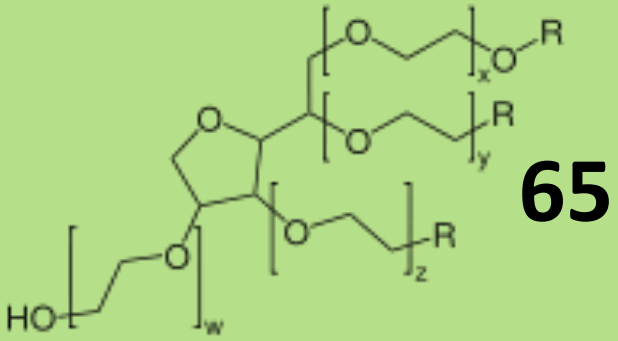
Polysorbates



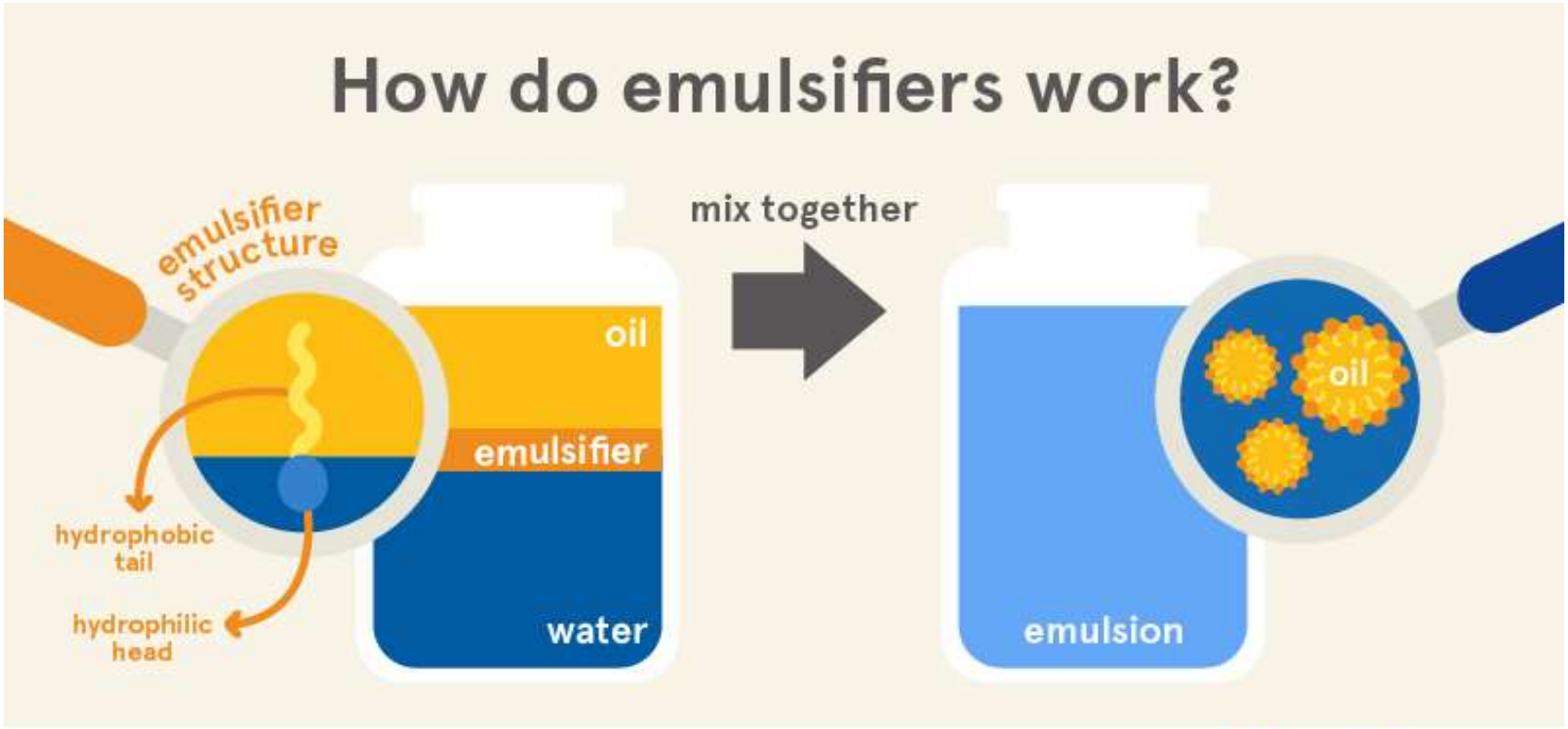








6. Emulsifiers



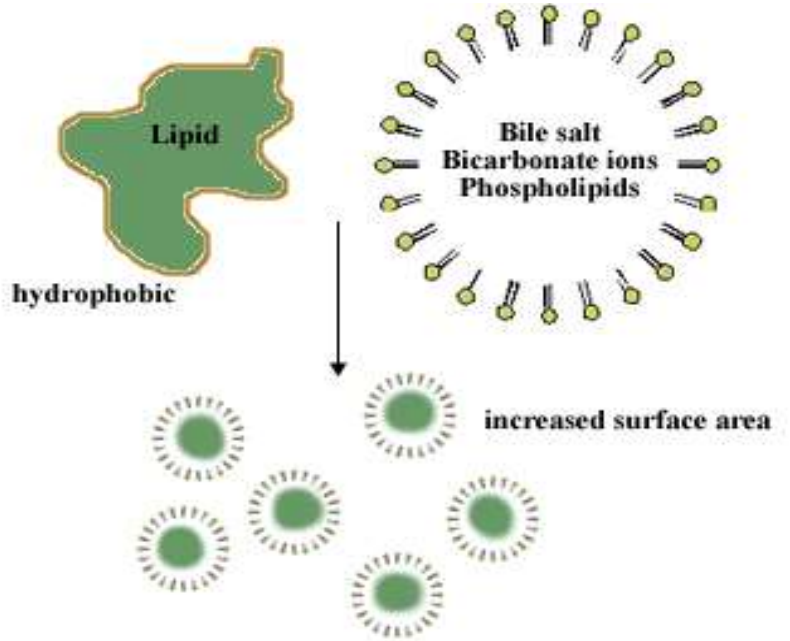
Co-funded by the European Union

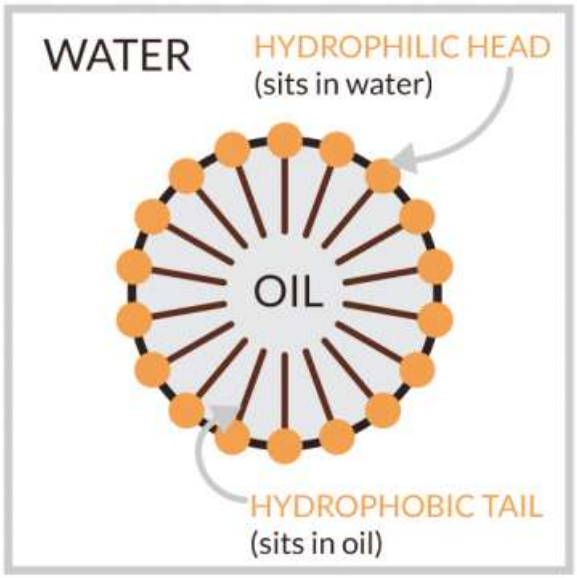
eufic

Food Safety 4EU

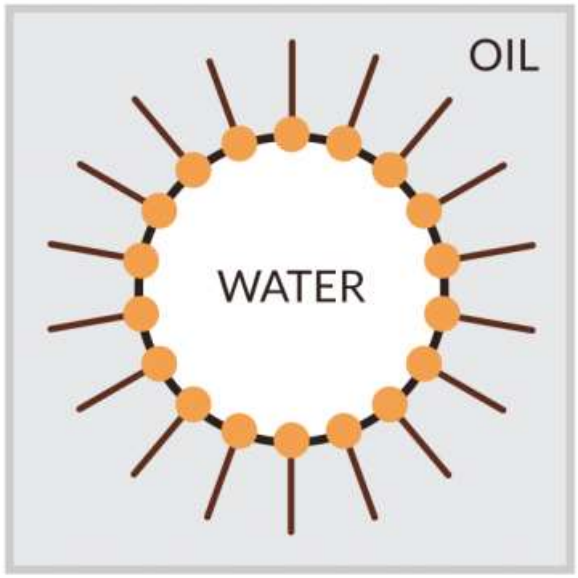
https://www.eufic.org/en/whats-in-food/article/what-are-emulsifiers-and-what-are-common-examples-used-in-food

6. Emulsifiers





HLB-value of an emulsifier PREDICTS the preferred system



6. Emulsifiers

application

- Margarine
- Mayonnaise
- Chocolate
- Ice cream
- Bread
- Desserts/Creams/Whipped cream/Mousse
- Biscuits/Cookies
- Soft drinks/Beverages
- Caramels
- Chewing gum
- Etc.

7. Hardeners

"substances that render or maintain the tissues of fruits or vegetables firm or crisp, or interact with coagulating agents for the preparation or enhancement of coagulation"

- **Calcium hydrogen sulphite (E227)**
  Beer, canned fruits/vegetables, jams, fruit juices, etc.
- **Calcium citrate (E333)**
  Ice cream, soft drinks, jams, condensed milk, cheeses.
- **Calcium phosphate (E341)**
  Canned fruits, powdered foods.

7. Hardeners

- **Calcium sulfate (E516)**

  Beer

- **Calcium chloride (E509)**

  Beer, canned fruits and vegetables, pickles, cheeses

- **Chloride (E511) and Magnesium sulfate (E518)**

  Cheeses

- **Aluminum sulfate (E520)**

  Cheeses

- **Calcium hydroxide (E526)**

  Cheeses

- **Calcium gluconate (E578) and Magnesium gluconate (E580)**

  Canned vegetables

8. Gelling agents

"Substances that give texture to a food by forming a gel"

- **Polysaccharides**
  (Starch, gums)
- **Proteins**
  (Gelatin, egg albumin, collagen)
- **Flours**




9. Thickening agents

"Substances that increase the viscosity of a food"

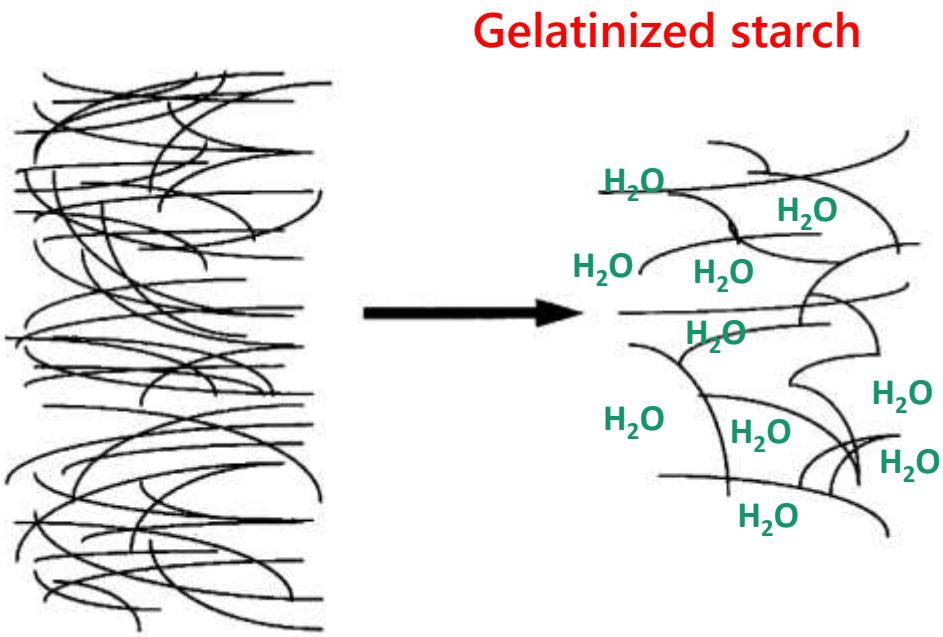
- **Alginate acid & salts with Na, Ca, K**
- **Agar**
- **Carrageenan**
- **Gums: oat, guar, acacia, tragacanth, xanthan, gelan, etc.**
- **Gelatin**
- **Dextrin, Maltodextrin**
- **Starch & Modified starches**
- **Bakery dough glucan**
- **Arabinogalactan**

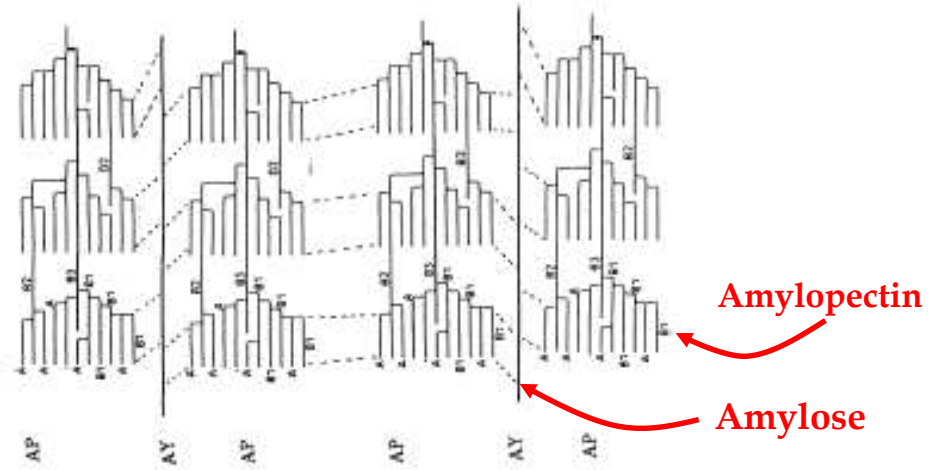
8,9. Gelling agents/thickening agents

Starch gels

When starch grains are in the presence of water:

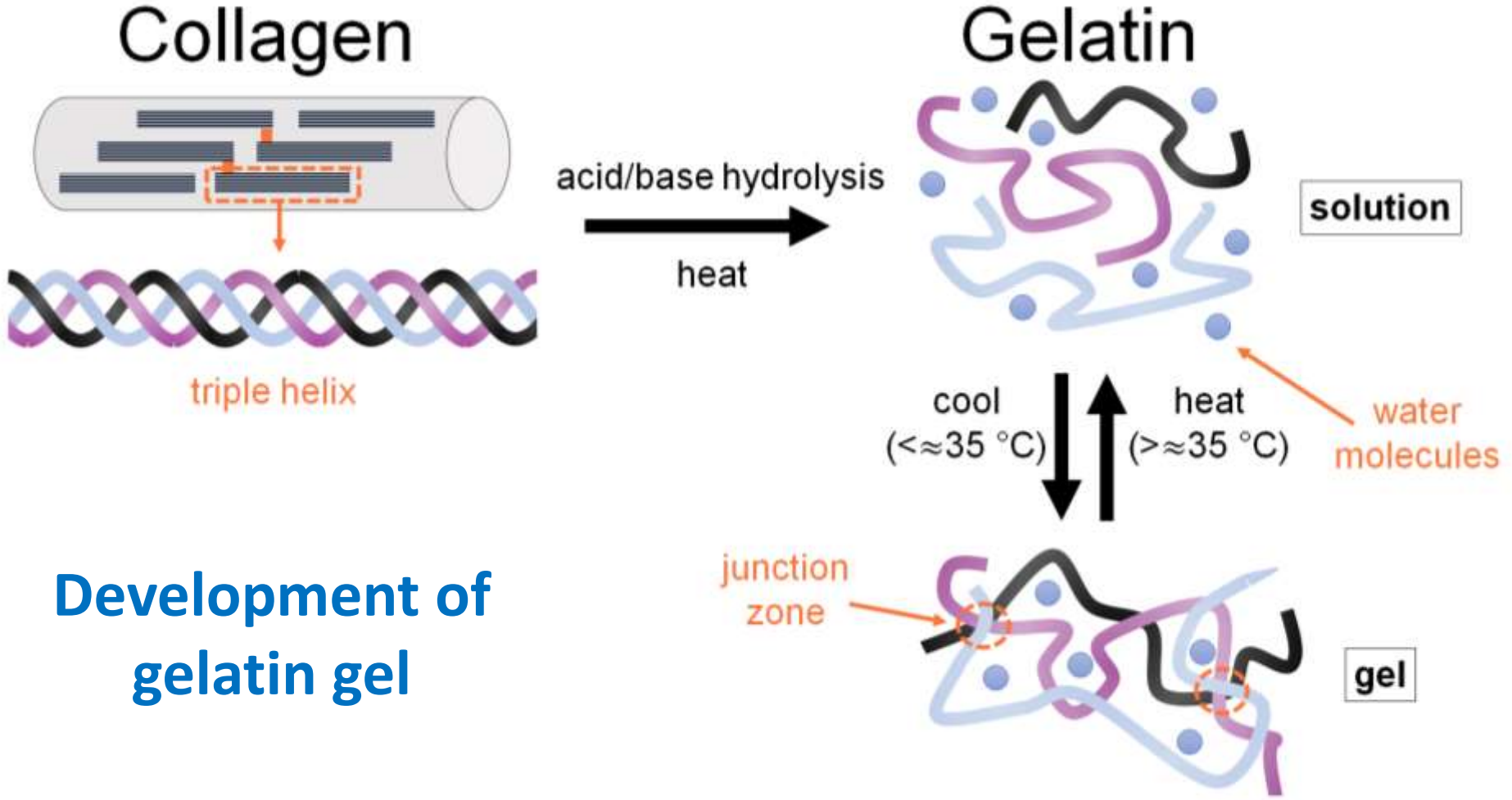
- They undergo slight swelling while maintaining their structure.
- With increasing temperature, **intermolecular H-bonds** are formed.
- The activity of water is significantly reduced, and the viscosity increases.
- The crystalline structure of starch is lost, and it undergoes **gelatinization**.





8,9. Coagulating agents/thickening agents

Protein gels: Gelatin

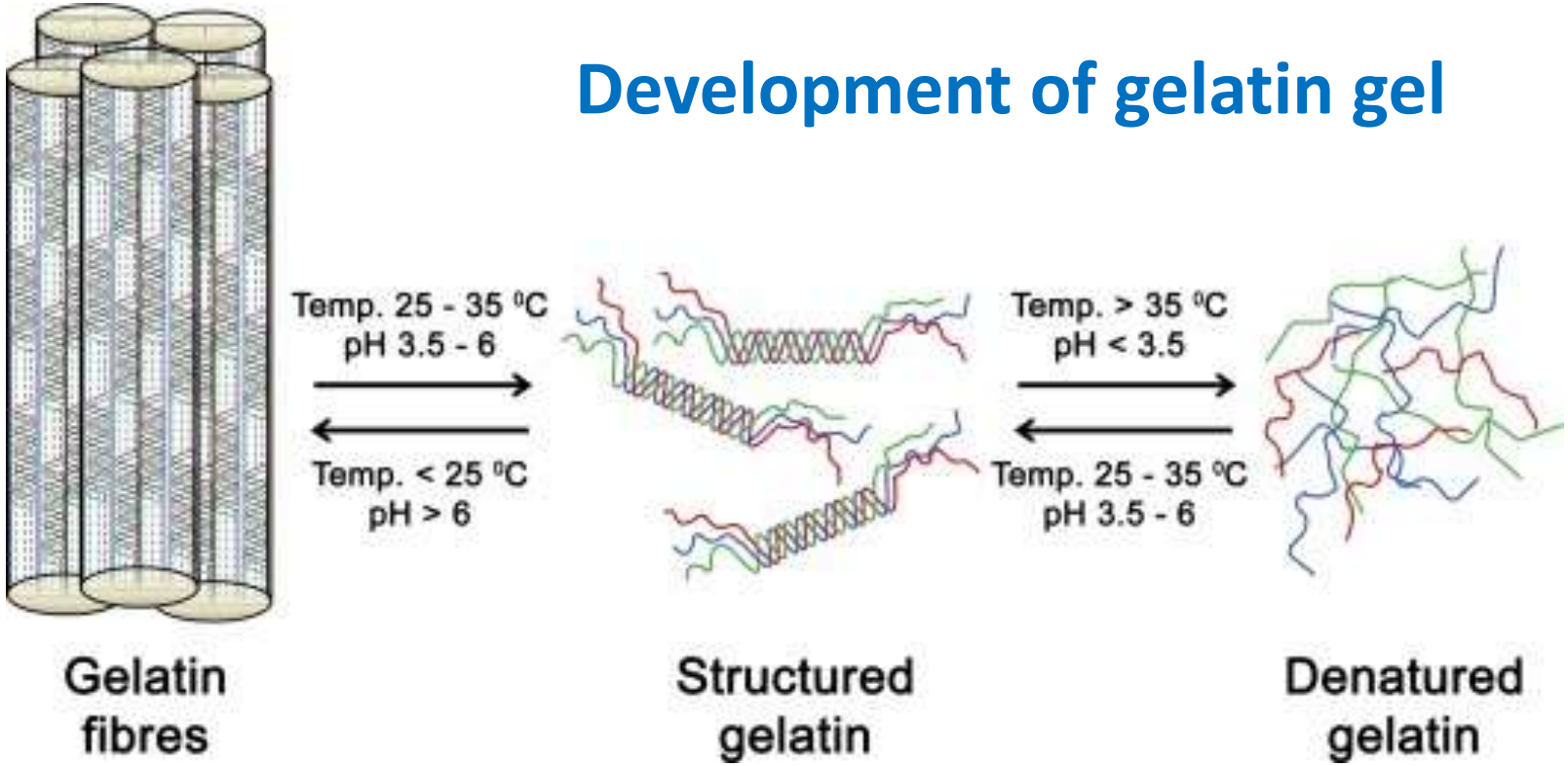


Development of gelatin gel

https://chembam.com/resources-for-students/the-chemistry-of/gelatin/

8,9. Coagulating agents/thickening agents

Protein gels: Gelatin



- **The transformation of collagen produces thermally reversible gelatin.**

10. Glazing agents

"Substances applied to the external surface of food to provide a shiny appearance or a protective coating"

E901 - Beeswax

E902 - Candelilla wax

E903 - Carnauba wax

E904 - Shellac

E905 - Microcrystalline wax (Petroleum wax, Paraffin wax)

E912 - Montanic acid esters (Montan wax)

E914 - Oxidized polyethylene wax

11. Humectants

"Hygroscopic substances that prevent the drying of food by reacting to a low humidity environment or promoting the dissolution of a powder in a liquid medium"

E965 - Maltitol
E967 - Xylitol
E420 - Sorbitol
E422 - Glycerol
E1518 - Glyceryl triacetate
E1520 - Propylene glycol
E1200 - Polydextrose

Applications:

- **Starch/jelly creams**
- **Toppings**
- **Sauces**
- **Salad dressings**
- **Caramels**
- **Bakery products**
- **Ice creams**
- **Etc.**

12. Modified starches

"Substances derived from edible starches that have undergone one or more chemical modifications. They may have undergone physical or enzymatic treatment and could have undergone acid or alkaline thinning or bleaching"

Applications as:

- **Thickening agents**
- **Gelling agents**
- **Stabilizers**
- **Emulsifiers**

12. Modified starches:

E1404 - Oxidized starch
Starch treated with sodium hypochlorite

E1410 – Starch dihydrogen phosphate
Starch esterified with orthophosphoric acid, Na or K orthophosphate, or Na tripolyphosphate

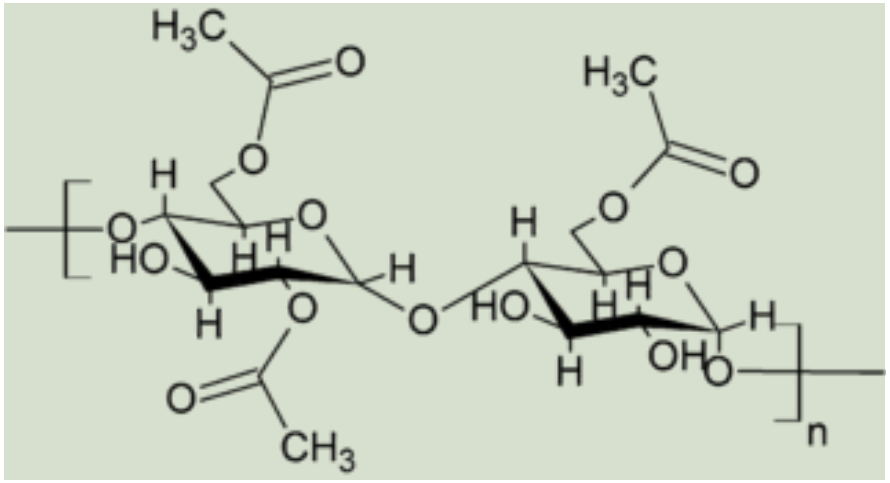
E1412 - Acid-treated starch
Cross-linked with Na trimetaphosphate or phosphoryl chloride

E1413 - Phosphorylated distarch phosphate
Combination of treatments such as in E1410 and E1412

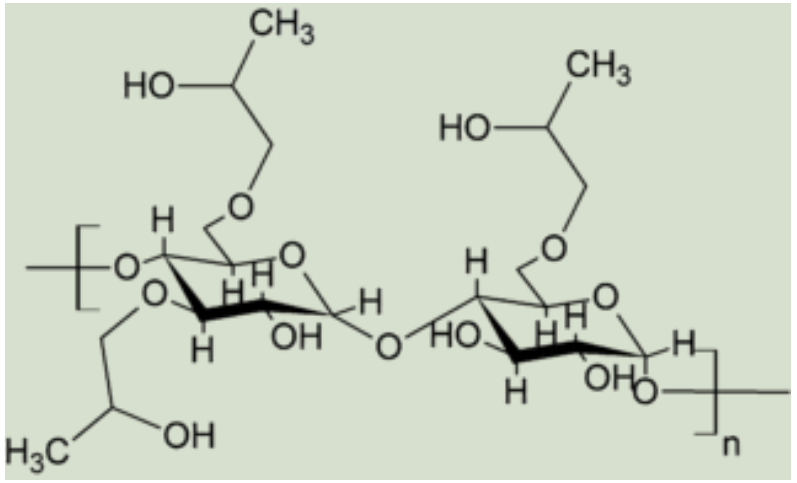
E1414 - Acetylated distarch phosphate
Cross-linked with Na trimetaphosphate or phosphoryl chloride and esterified with anhydrous citric acid or vinyl ester

And many more…

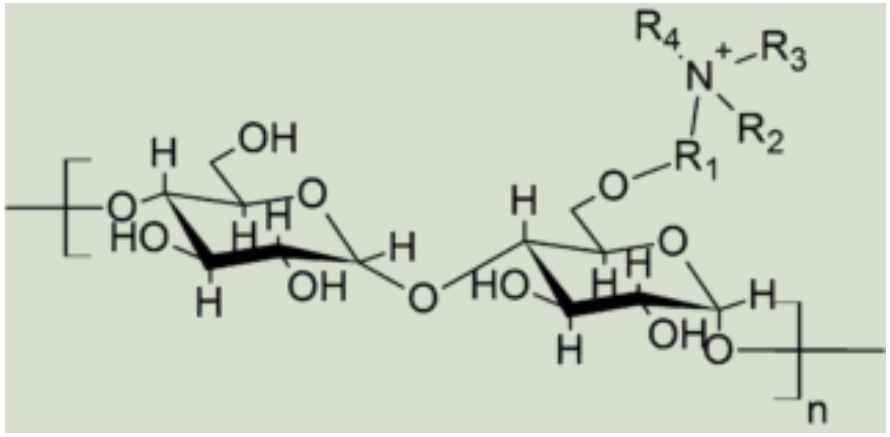
12. Modified starches



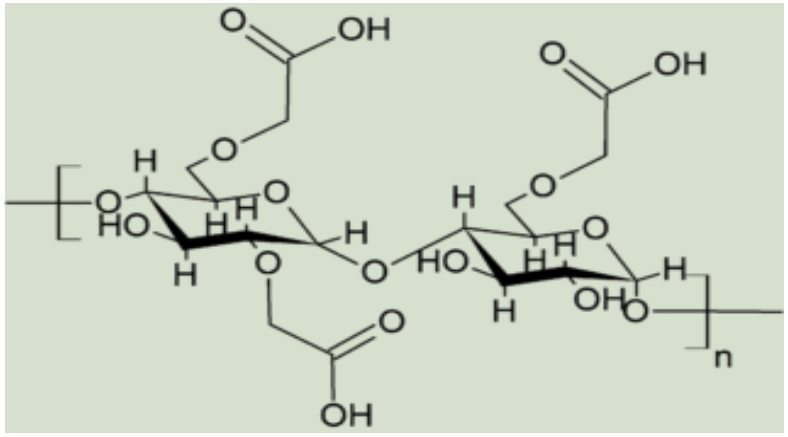
Oxidized starch



Hydroxypropyl starch



Cationic starch



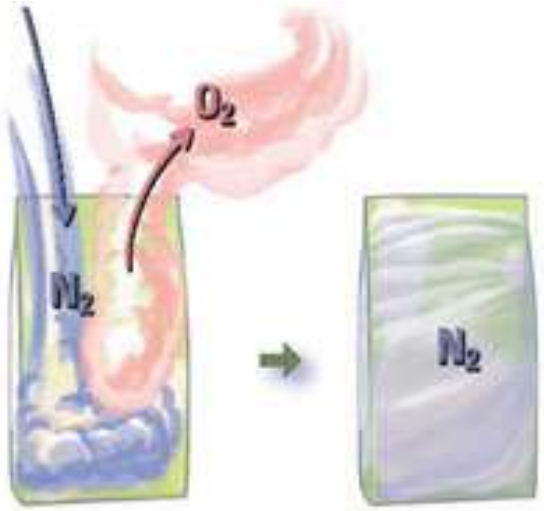
Carboxy Methyl Starch (CMS)

Copywrite:https://en.wikipedia.org/wiki/Modified_starch

13. Packaging gases

"gases other than air that are introduced into a container before, during, or after placing food in said container" (modified atmosphere environment)

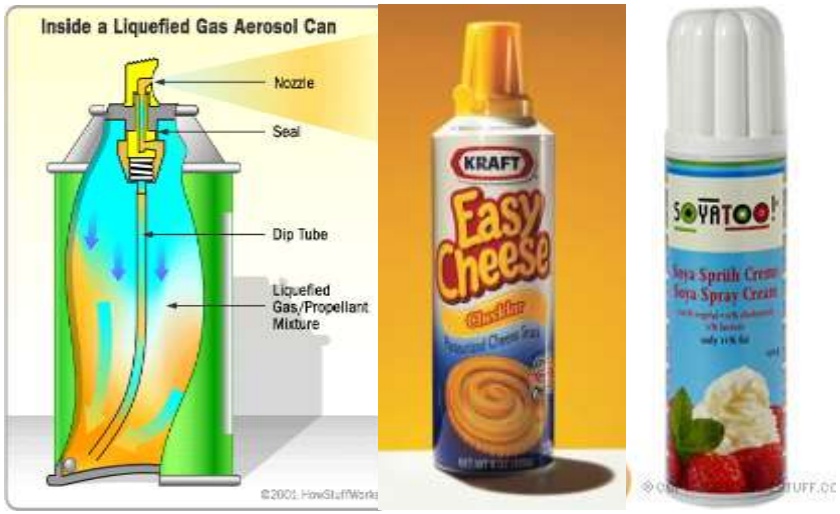
E938 Argon
E939 Helium
E940 Dichlorodifluoromethane (*)
E941 Nitrogen
E948 Oxygen
E949 Hydrogen (*)



***repealed either for being explosive or for depleting the ozone layer**

14. Propellants

"Gases other than air that cause the expulsion of food from a container"



E941 Nitrogen
E942 Nitrous oxide
E943a Butane (*)
E943b Isobutane (*)
E944 Propane (*)
E945 Chloropentafluoromethane (*)
E946 Octafluoromethane (*)

*repealed either for being explosive or for depleting the ozone layer

15. Raising (or leavening) agents in baking

"Substances or combinations of substances that release gas and therefore increase the volume of the dough or batter"

A) Chemical substances (pharmaceutical grade) of an alkaline nature that "contain" (release) CO_2 or NH_3

E500ii: Sodium bicarbonate (baking soda)

E503i: Ammonium bicarbonate (baker's ammonia)

E503ii: Ammonium carbonate (neutral ammonium carbonate)

15. Raising (or leavening) agents in baking

B) Mixtures of raising agents (baking powders)

Powdered sodium bicarbonate with inert ingredients (starch, flour, calcium lactate, calcium carbonate) and another ingredient such as:

E344 Citric acid

E 336i Potassium bitartrate (cream or tartar)

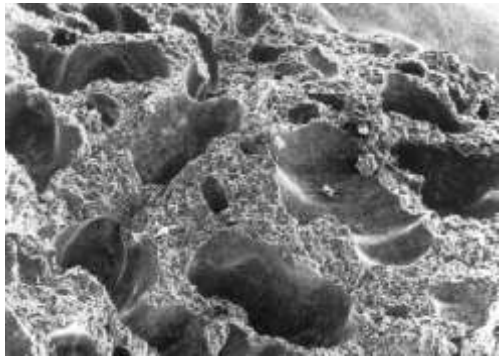
Phosphoric salts (E339, E340, E341, E343, E450, E451, E452)

15. Raising (or leavening) agents in baking

Mode of action: (a) Gas production after dissolution and in the presence of an acid (e.g. acid from milk, yogurt, orange juice) and/or **(b)** Gas production during baking.

$$\underset{\text{potassium hydrogen tartrate}}{HCOO\text{-}CH(OH)CH(OH)\text{-}COOK} + \underset{\text{baking soda}}{NaHCO_3} \rightarrow$$

$$NaCOO\text{-}CH(OH)CH(OH)\text{-}COOK \text{ (potassium sodium tartrate)} + \uparrow CO_2 + H_2O$$



Gas (CO_2) bubbles in the dough

15. Raising (or leavening) agents in baking

Sodium bicarbonate (baking soda) **+ Acid** (vinegar, lemon juice, etc.)**:**

$$NaHCO_3 + H^+ \rightarrow Na^+ + \uparrow \mathbf{CO_2} + H_2O$$

Sodium bicarbonate (baking soda) **+ Calcium dihydrogen phosphate:**

$$14\ NaHCO_3 + 5\ Ca(H_2PO_4)_2 \rightarrow$$
$$\uparrow \mathbf{14CO_2} + Ca_5(PO_4)_3OH + 7\ Na_2HPO_4 + 13\ H_2O$$

Potassium bitartrate (cream of tartar) **+ Sodium bicarbonate** (baking soda)**:**

$$HCOO\text{-}CH(OH)CH(OH)\text{-}COOK + NaHCO_3$$
$$\rightarrow NaCOO\text{-}CH(OH)CH(OH)\text{-}COOK + \uparrow \mathbf{CO_2} + H_2O$$

16. Flavor enhancers

"Substances that enhance the existing taste and/or aroma of food"

E620 Glutamic acid

E621 Monosodium glutamate (MSG)

E622 Monopotassium glutamate

E623 Calcium glutamate

E624 Ammonium glutamate

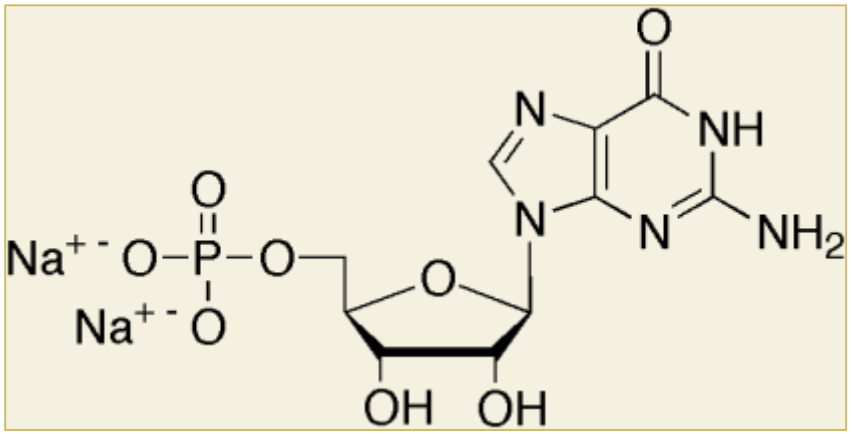
E625 Magnesium glutamate

E626 Guanylic acid

E627 Sodium guanylate

E628 Potassium guanylate

E629 Calcium guanylate



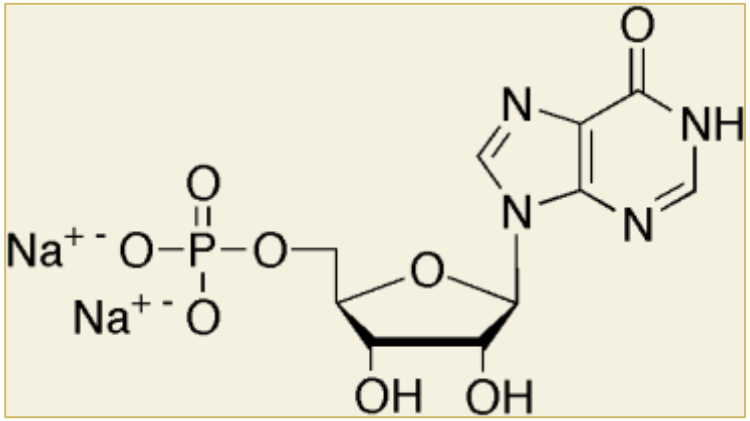
16. Flavor enhancers

E630 Inosinic acid

E631 Sodium inosinate →

E632 Potassium inosinate

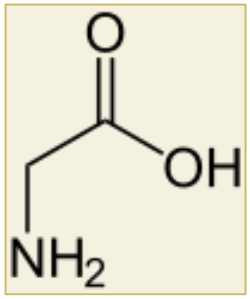
E633 Calcium inosinate

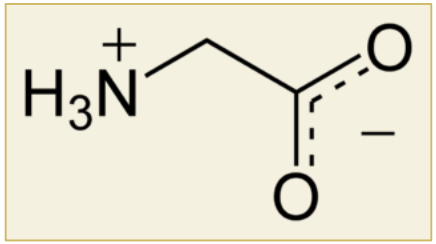


E634,5 Salts of 5'-ribonucleotides with Ca and Na (mixtures of guanylates and inosinates)

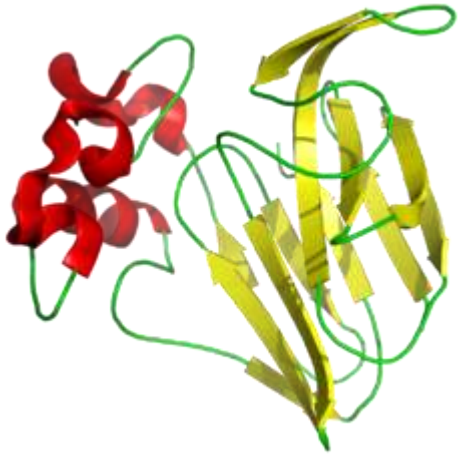
E640 Glycine and its sodium salt →

E650 Zinc acetate



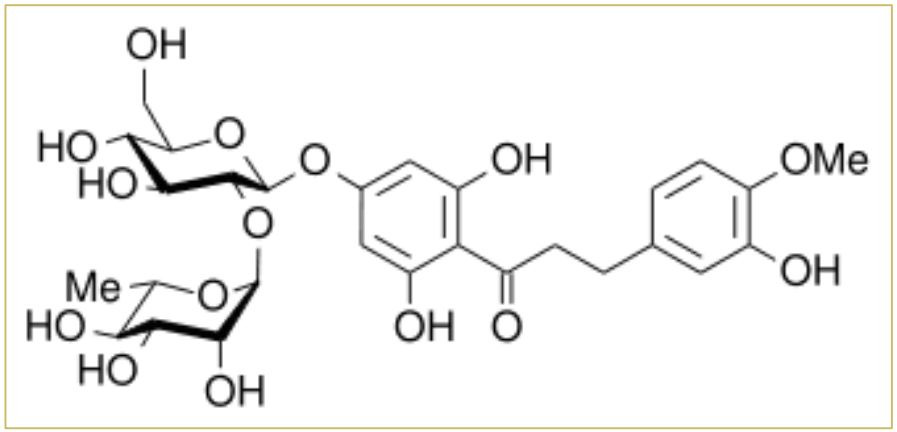


16. Flavor enhancers



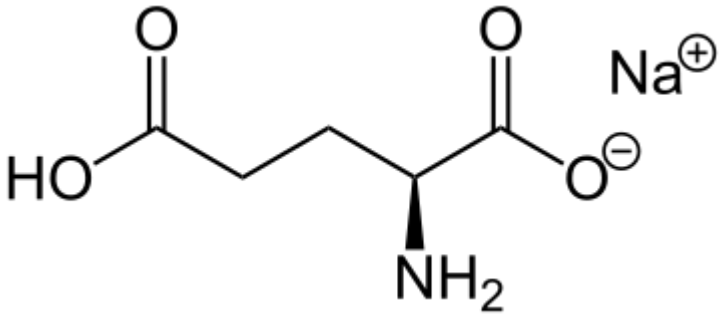
E957 Thaumatin

E959 Neohesperidin (dihydrochalcone)



16. Flavor enhancers

E621 Monosodium glutamate (MSG)



$HOOC\text{-}[CH_2]_2\text{-}CH(NH_2)\text{-}COONa$

- It is traditionally made from wheat gluten
- Today, produced by fermentation of starch, sugar, molasses, etc. with *Brevibacterium*, *Arthrobacter*, *Microbacterium* & *Corynebacterium* bacteria
- In Asian cuisine: seaweed extract, rich in glutamic acid is used

16. Flavor enhancers

E621 Monosodium glutamate (MSG)

16. Flavor enhancers

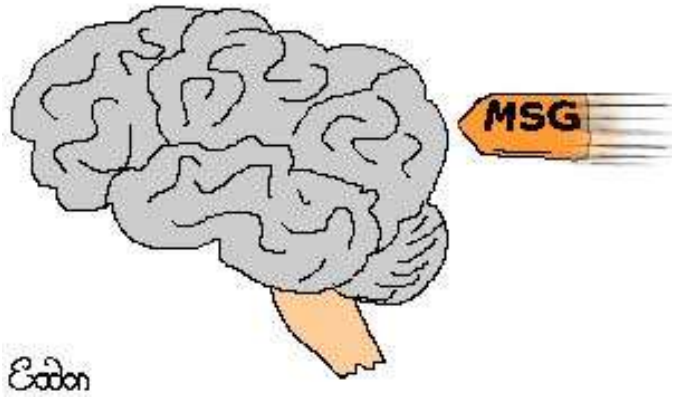
E621 Monosodium glutamate (MSG)

Chinese Restaurant Syndrome (?)

(expressed in *1968 by Robert Ho Man Kwok: «Chinese restaurant syndrome», New England Journal of Medicine*)

Symptoms:

- ✓ **Onset: 15 to 20 min after consumption**
- ✓ **Duration: 2 hours**
- ✓ **Tingling sensation in the back of the throat and then in the hands and chest**
- ✓ **Weakness**
- ✓ **Rapid heartbeat**



17. Chelating agents

"substances that form chelates with metal ions"

- ✓ **Binding metals such as Cu, Ni, Fe**
- ✓ **Preventing degradation of food quality through the catalysis of oxidative reactions by metals**

E385 Calcium disodium EDTA (Ethylenediaminetetraacetic acid)

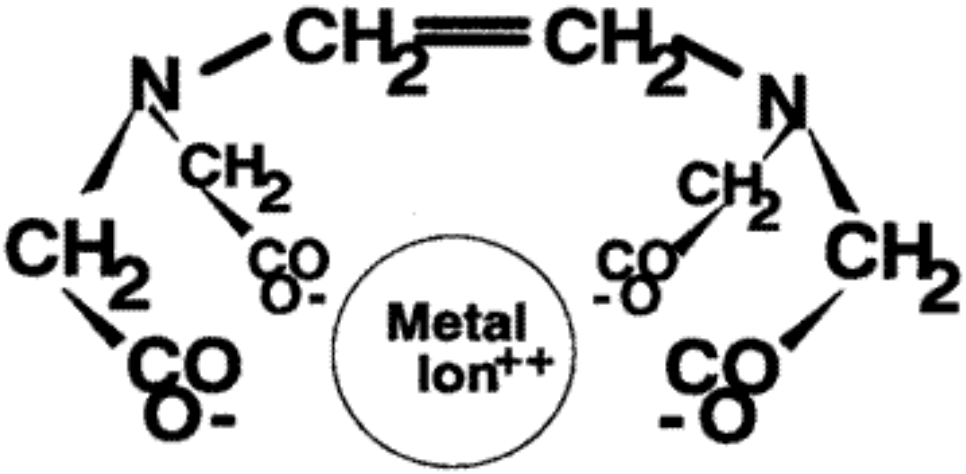
E509 Calcium chloride

E575 Glucono-delta-lactone

E576 Sodium gluconate

E577 Potassium gluconate

E333 Calcium citrates



Thank you !