Ecodesign in Food packaging

Unit 3: Concepts of food degradation and preservation methods

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After learning this unit, the student will be able to:

- Objective 1: To understand the causes of deterioration of food
- Objective 2: To know the principles and methods of food preservation.

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3.1 Food Degradation

Regarding to the food degradation it is possible to distinguish several situations:

- Food contamination – the Presence of foreign bodies (ex. dust, hair, glass, etc.);
- Ageing of the food – Process that determines the loss of some nutritional and sensory characteristics which foods have them fresh;
- Food alteration - Process that determines the change of appearance and smell of food, making them inedible.

The alteration can be produced by the action of some factors of physical nature (light, heat), chemical (oxygen, water) or biological (enzymes and microorganisms), or a combination of these. For example, some enzymes are internal factors of spoilage of the fresh products which are activated to light, fruits and natural juices contain enzymes that in the presence of oxygen in the air causing abnormal odors or tastes.

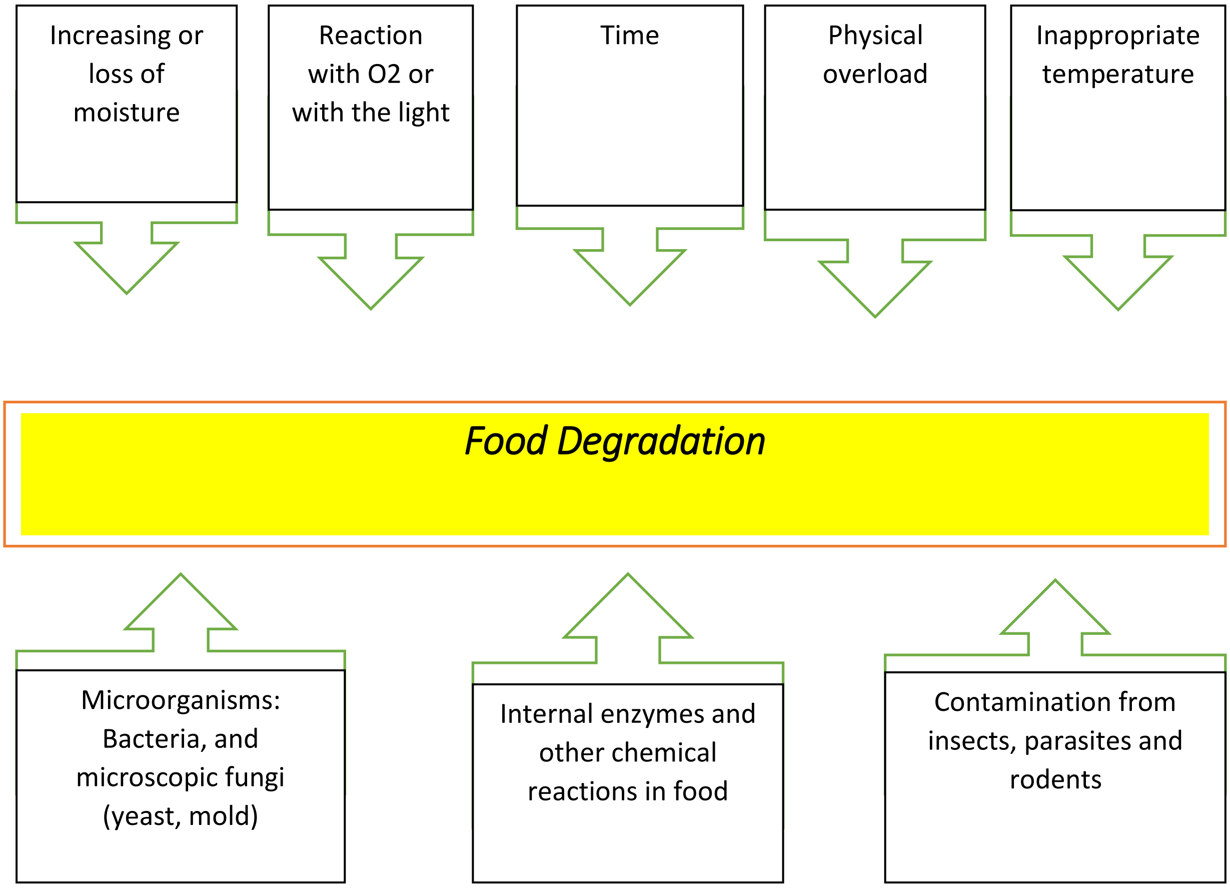

***Fig. 1:* Factors that contribute to the deterioration of food (processing after http://wiki.ubc.ca/Course:FNH200 lesson05)**

Enzymes

The enzymes, ((from the Greek "en zime" = yeast), are globular complex proteins from living organisms which catalyzes the acceleration of the rate of biochemical reactions. Without them the fruit would not ripen, the seeds would not germinate, we couldn't think, we couldn't digest the food and absorb the nutrients present in them etc. Enzymes are involved in thousands of biochemical processes that take place in our body.

The action of enzymes[1] can be used with beneficial effects in the food industry, for example, in the manufacture of the cheese. However, in order to preserve and extend the shelf life of food, usually, it is necessary to inactivate enzymes present in food and on the surfaces of the packaging using heat or chemical means. Fruits and vegetables, which are major sources of enzymes, provides many examples of the nature and action of these agents of the food destruction. Some of these can be inactivated by moderate heat treatments, while others require a few minutes at temperatures of sterilization. During fruits ripening, the activity of some enzymes increases and, consequently, causes a softening of the tissue. In potatoes, inhibitors of enzymes play an important role in balancing the rate of biochemical reactions related to accumulation of sugar. This is important for the storage and conditioning of potatoes before processing, where the presence of reducing sugars is undesirable because they can lead to the intensification of reactions which causes the discoloration by the so-called reaction " enzymic browning". Also, it occurs in vegetables and fruits due to damage or cutting of the surface and exposure to air. For the inactivation of the enzyme it uses citric acid, malic, phosphoric or it avoids the contact with the oxygen in the air by immersion in brine, or by packing.

The fruits packaging in an atmosphere which excludes the air will reduce the degree of reaction of discoloration, but may lead to quality problems and it is not a viable solution. Enzymes are also produced during the microbiological alteration of foods and are often involved in breaking the texture. Many of the microorganisms which secrete enzymes are molds. There are bacterial species that produce amylases, enzymes that are stable to heat. Amylase degrades the starch, reducing viscosity. The inefficiency of the enzymes inactivation often reduces the shelf life of the packaged food. This is rarely a problem for preserved foods, but it is a factor to be taken into account for frozen fruits and vegetables to which it applies only a process of blanching before freezing. Blanching is intended to inactivate the majority of enzymes, without imposing the excessive thermal deterioration of foods and, therefore, to do this it uses moderate temperatures (90-100 ° C) and short durations of heating (1-10min). To defrost it can be observed an enzymatic activity renewed, probably due to regeneration of the internal enzymes.

[1] FOOD PACKAGING TECHNOLOGY- Edited by RICHARD COLES- Consultant in Food Packaging, London, DEREK MCDOWELL Head of Supply and Packaging Division Loughry College, Northern Ireland and MARK J. KIRWAN Consultant in Packaging Technology, London – 2003 by Blackwell Publishing Ltd

Microorganisms

The term is used to name all living beings that are not visible with the naked eye and to see them you need to use a microscope.

There are many types of micro-organisms, of different forms and structures more or less complex. Bacteria, moulds and yeasts are those about which is the most talked about concerning the spoilage of food. In terms of diseases transmitted through food, we can say that bacteria are the main responsible. Very many factors contribute to the presence of microorganisms in food. The presence of pathogens (microbes, viruses, parasites, prions) and cross-contamination[2] are believed to be ,,sources” of microorganisms in food[3] .

Various types of microorganisms can cause changes in the character of the food, which can be "positives" or "negatives".

– Products with "positive" microbial changes include cheese, yogurt and wine, to which can be also an increasing of the nutritional value or keeping quality of the products for a short period of preservation.

– The negative aspects of microbial growth include food spoilage by decay and food poisoning, mainly caused by different bacteria and less widespread. As they grow, microorganisms release their own enzymes into the liquid surrounding them and absorb the products of external digestion. This is the main cause of the food microbial alteration, which decreases its nutritional value.

Adjusting the temperature is the most commonly used method to destroy or to control the number of microorganisms present in the food and on the surfaces of the pack.

- Bacteria can have different shapes: Round, called cocci, rods shape, called bacilli, spiral shape, called spirocheți. Water is essential for the growth of bacteria, because it facilitates the transport of small molecules through the outside cytoplasmic membrane of the bacterial cell due to osmotic pressure. The bacteria require a higher level of available water than yeasts or moulds. At 20% available water, their growth is good, but it is limited when it is reduced to 10%, and at 5% there is not a bacterial growth. Water activity (available water) – Aw, in the field of food, is defined as the partial pressure of the water vapors in the food reported to the partial pressure of the pure water vapors at the same temperature. Using this special definition, pure distilled water has an activity value of a unit. As the temperature increases, the Aw usually increases, (with the exception of some products like crystal salt or sugar). Substances with values of Aw greater tend to support more microorganisms. Bacteria usually require at least Aw=0,91, and fungi at least 0.7. A table with values of water activity in the food and with the one supported by various microorganisms, is presented in annex 1.[4]

- Fungi are a group of microorganisms that are found in nature on plants, animals and human beings. The different species of fungi vary greatly in their structure and reproductive method. The fungi can be unique organisms, round or oval, or structures with more cells with threads. The threads may form a network, visible to the naked eye, in the form of the mold (e.g., on bread and cheese). The fungi are divided into yeasts and molds.

- Yeast may have sizez between 2-100 µm. They reproduce by flowering, which is an asexual process. During flowering, a small bud develops on the cell wall of the mother cell, having cytoplasm common with the mother, after which the bug will be separated from it by a double wall. The new cell does not always separate from her mother, she can stay attached, while this can form new buds. The newly formed cell may form, in turn, muds. In the end, can result large groups of cells attached to each other. Yeasts can form spores that can be relatively easily destroyed by technological processes at moderate temperature and on the surfaces of packaging with moderate temperature or sterilization.

- Molds belong to a broad category of fungi with multicellular fibers. They attach to food, using long fibers that are the vegetative part of the mold. Reproduction can be asexual and it results in the production of a large number of spores, or sexual, that can be a response to the environmental changes - with the production of spores much more resistant, which like bacterial spores, can stay dormant for a while. The spores are very small and lightweight and can be transported in a huge number on the surrounding surfaces, they being the key of the contamination to the food packaging. The treatment with steam of the cover, the overthrow of the dish immediately after sealing or a pasteurization process, can prevent the deterioration of the preserved food. One of the most important drugs for the treatment of bacterial infections, penicillin, is derived from the Penicillium mold. The emergence of the formation of spores of this mould is indicated by the formation of a miniature green bush. The family of Penicillium molds produces enzymes converted to fats and proteins, which are key agents in the ripening of blue cheeses (Penicillium roquefort) and Camembert (Penicillium camembert)[5] .

[2] Cross-contamination represents the direct or indirect crossing of pathogens from raw contaminated food to other foods.

[3]The microorganisms and food poisoning-Lifelong learning programme Leonardo da Vinci.

[4]http://en.wikipedia.org/wiki/Water_activity

[5] FOOD PACKAGING TECHNOLOGY- Edited by RICHARD COLES- Consultant in Food Packaging, London, DEREK MCDOWELL Head of Supply and Packaging Division Loughry College, Northern Ireland and MARK J. KIRWAN Consultant in Packaging Technology, London – 2003 by Blackwell Publishing Ltd

Other factors, that affect the growth of microorganisms:

- Internal factors:

• Moisture content, water Activity –Aw
• pH
• Available nutrients
• The physical structure of the food
• The potential of oxidation-reduction (redox)
• The presence of antimicrobial agents. Some foods intrinsically contain natural antimicrobial compounds that transmit a specific level of microbiological stability. There is a number of antimicrobial constituents plant-based, including many essential oils, tannins, glycosides and resins, which are found in some foods. Specific examples include cloves, garlic, cinnamon, mustard, sage and oregano. Some foods animals-based also contain antimicrobial constituents (examples include cow's milk, eggs, fresh meat, poultry and seafood) . The usual concentration of these compounds in formulated foods is relatively low, so that the antimicrobial effect alone is weak. However, these compounds can produce a higher stability in combination with other factors and procedures which are indicated in section.3.2.

- External factors (see section 3.2):

• Temperature
• Relative moisture
• Carbon dioxide or oxygen
• Types and numbers of microorganisms in foods

– **In annex 1** shall indicate a few values of Aw. Most fresh foods, such as fresh meat, vegetables and fruits, have values close to the optimum level for growth of most microorganisms (0,97 - 0,99). **The influence of moisture content** can be reduced by:

• Reducing Aw – inhibition of microbial growth by drying or by adding solutes (sugars, spices, or salts).
• Drying by cold - extraction of water from frozen food under vacuum.
• Enriching solutions - Sugar for fruits and salts for meat and fish.

– In annex 2, presents the influence of pH in the development of micro-organisms for different foods, as follows: Tab. 1, the pH[6] level for the development of some microorganisms, Tab. 2, the approximate level of pH for certain foods. In general, microorganisms do not grow, or grow very slowly at pH<4,6.

– **Available nutrients**. Microorganisms require certain basic nutrients for growth and maintenance of metabolic functions. The amount and type of necessary nutrients vary depending on microorganisms. These nutrients include water, a source of energy, nitrogen, vitamins and minerals. The variable quantities of these nutrients are present in foods. Meat has abundant proteins, lipids, minerals and vitamins. Most muscle foods have low levels of carbohydrates. Vegetable foods have high concentrations of different types of carbohydrates and different levels of proteins, minerals and vitamins. Foods such as milk and dairy products and eggs are rich in nutrients. Food microorganisms can get energy from carbohydrates, alcohols and amino acids. Most microorganisms will metabolize simple sugars, such as glucose. Others can metabolize more complex carbohydrates, such as starch or cellulose, found in vegetable foods or glycogen found in muscle foods. Some microorganisms can use fats as an energy source. Amino acids serve as a source of nitrogen and energy and are used by most microorganisms. Required minerals for microbial growth include phosphorus, iron, magnesium, sulphur, manganese, calcium and potassium. Generally, small quantities of these minerals are required, so a wide range of foods can serve as good sources of minerals.

– **The physical structure of the foods**. Derived foods from plants and animals, in particular in the raw state, have biological structures that may prevent the entry and growth of pathogenic microorganisms. Examples of such physical barriers include the peel of the seeds and fruits, the peel of the vegetables, peel to nuts, the skin of animals, bark to egg, etc. Physical damage due to handling during harvest, transport or storage, as well as invasion of insects can allow the penetration of microorganisms. During food preparation, processes such as slicing, cutting, milling, shelling, will destroy the physical barriers. Thus, the interior of the food may become contaminated and may occur a growth of microorganisms depending on the time and temperature of storage.

– **Reactions of reduction-oxidation (redox)**. The reactions that occur with the acceptance or donation of electrons are called reactions of oxidation-reduction. The reduction occurs through the acceptance of electrons, and the substance is called oxidizing agent. The oxidation occurs with the loss of electrons, and the substance is called reducing agent. Because in the solution there are no free electrons, always donated electrons by a species are accepted by another, and therefore a reaction of oxidation is always followed by a reaction of reduction.

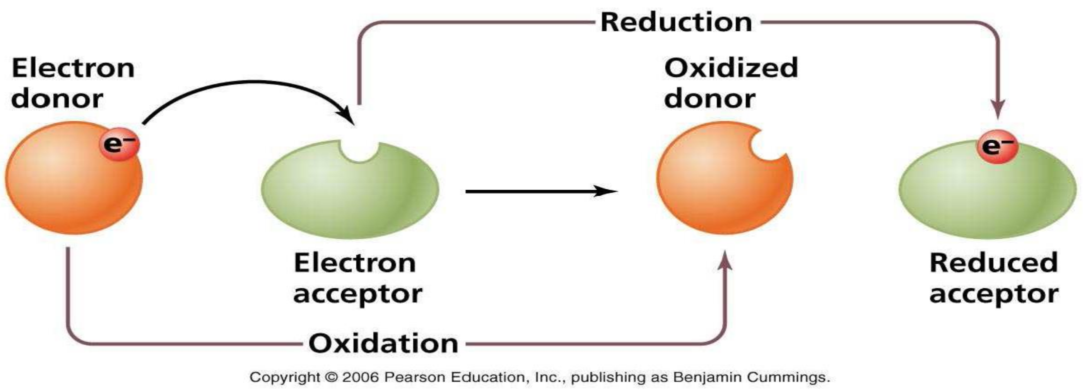

***Fig. 2:* Illustration of the redox reaction in a solution.**

[6]The pH (Hydrogen potential) shows the acidic or basic character of a solution.

Redox potential Eh, represents the potential difference between an inert electrode and a solution containing the two forms of the studied redox system (oxidized and reduced). The absolute value of the potential can not be measured.

Is measured the relative value to a reference electrode whose potential is defined as being equal to 0. The values are expressed in millivolts – mV. The values range between 0 and -800 mV, are the ones that can be considered as beneficial or detrimental. Over the value of 800mV, the Eh site is considered too strong for the human body so it is not advisable to consume food or beverages with Eh value over this limit. If this value is positive (+) the solution has oxidising properties. The negative value (-) indicate a reducing solution. An oxidation electrode, standard, fully oxidized will have an Eh of +810 mV at pH 7.0, 30 ° C, and under the same conditions, a hydrogen electrode, standard, completely reduced will have an Eh of -420 mV. Eh depends on the substance pH. Measurements of Eh can be used in combination with other factors to assess the growth potential of the pathogen. In annex 3, are presented a few values of Eh and pH corresponding to several foods. In general, the range at which the microorganisms can grow, is: aerobic + 500 -+300 mV; facultative anaerobes +300 to -100 mV; and anaerobic +100 to less than -250 mV [7].

3.2 The principles of the technologies for limitation of the food deterioration

The main technologies for limitation of the food deterioration are presented in UNIT I, section 1.2.

The principles that underpin technologies for limitation of the food deterioration are presented below.

Thermal processing:

- Most bacteria are destroyed at 82-93°C, but the spores are not destroyed.
- To ensure sterility is required a wet heating at 121°C for 15 minutes.
- Acid foods, see annex 2, require less heat.

[7]Evaluation and Definition of Potentially Hazardous Foods-Chapter 3. Factors that influence Microbial Growth- US Food & Drug Administration

Pasteurization

- It destroys pathogens and substantially reduces number of microorganisms

- Different procedures of thermal pasteurization, for different periods of time are described in the unit 1. The shorter time of heating has as a result improving the food flavour.

Preservation by cold

- Frozen foods (-10° C) usually don't have water in the free state (is reduced Aw)

- Freezing can destroy some microorganisms, but not all

- It appeared the method that uses temperatures below -10°C

- Once frozen, the foods must not be refrozen.

Drying

- The food dehydration also dehydrates microorganisms, which contain approx. 80% water.

- Drying by freezing (freeze-drying) is the most effective method of food drying.

Adding sugar or salt

- One of the oldest methods of conservation

- Each of them can be added to a food product to increase the food affinity for water

- It decreases Aw in foods

- It removes water from microorganisms by osmosis.

The smoke

-It contains formaldehyde and other preservatives.

- The heating during smoking process helps to reduce microbial populations and dries the food.

- The smoke can be toxic for humans

The use of wood smoke for food preservation is almost as old as the drying in the open air. Although, it is used to reduce the moisture content of the food due to the heat associated with the generation of smoke, it has also the effect of drying. The smoke is mainly used for meat and fish. The smoke does not only give the desired flavor and color of certain foods, but some of the formed compounds during the smoking process have also preservative effect (bactericidal and antioxidant).

The atmosphere

- The air is removed for the control of aerobic microorganisms;

- It ensure air for the control of anaerobic microorganisms;

- Carbon dioxide and nitrogen are added;

- Most fruits and vegetables emit ethylene; ethylene accelerates the ripening process; for the extension of shelf life, ethylene should be removed.

- Packaging with controlled atmosphere[8] (MAP - Modified atmosphere packaging), are generally used in combination with refrigeration to extend the shelf life of fresh food, perishable (meat, fish and cut fruits, as well as various bakery products, snack foods and other dry foods). Many MAP foods are packed in the transparent foils to allow the customer's retail to see the food. Unprocessed fruits and vegetables continue to breathe after they have been packaged, they consume oxygen and produce carbon dioxide. Using packaging with specific features of permeability, the levels of these two gases can be controlled during the shelf life of food. Alternatively, an active packaging can be used, in which are incorporated chemical adsorbents (ex. to remove the gases or water vapors from the package). Also, an alternative is packaging in vacuum, where all the gas from the package is removed. This is a very effective method to delay the chemical changes, (ex. rancidity), but it must be prevented by pasteurization, the growth of the pathogen, C. botulinum, which grows in anaerobic conditions.

Preservation by acidification

We meet natural acidification (pickling) or artificial acidification (sailor). The fruits, vegetables and meat are preserved by the use of acids. The acid is generally supplemented with salt or sugar. For their flavor and anti-infective action are added spices (onion, garlic, pepper, cloves, bay leaves, etc.). Adding oil in pickles form an impermeable layer of oil, which helps to prevent contact with air. Cucumbers, beef, peppers and some vegetables can be preserved by immersion in specially prepared liquid. This technique involves the food dipping into a certain liquid chemical that prevents the growth of microorganisms, but at the same time it maintains the edible food. The preserving liquids used are vinegar, brine, alcohol and some oils.

[8]FOOD PACKAGING TECHNOLOGY- Edited by RICHARD COLES- Consultant in Food Packaging, London, DEREK MCDOWELL Head of Supply and Packaging Division Loughry College, Northern Ireland and MARK J. KIRWAN Consultant in Packaging Technology, London – 2003 by Blackwell Publishing Ltd

- ***Preserving food by pickling*** is based on the creation of optimal conditions for carbohydrates fermentation under the action of lactic acid bacteria, resulting lactic acid which has the property to inhibit the harmful bacteria and which catalyze the biochemical processes of maturation. Preserving food by pickling is applied to obtain the acid dairy products (yogurt, buttermilk, cottage cheese) and preserving vegetables and fruits (cabbage, cucumbers, tomatoes, olives), and some vegetable and fruit juices from which therapeutic products are obtained. To increase the degree of acidity is used the addition of kitchen salt (NaCl). The brine pH will keep in the range of 3.4 to 4.1. In the souring by fermentation, the preservation agent is produced by the food itself during the fermentation process. Many weak organic acids, lipophilic (with affinity for fatty substances), act to obtain a low pH and to inhibit microbial growth. Thus, the propionic, sorbic and benzoic acids are very useful food preservatives. Organic acids are more effective at preservation, in undisociated state. The decrease of the pH of a food product increases the efficiency of an organic acid to preservation. Table 3, annex 2, presents the proportion of total undisociat[9] acid at different pH values for the selected organic acids. The type of organic acid used can influence essentially the quality of microbiological maintenance and food safety.

- ***Preserving food by sailing*** (artificial acidification) is a method of artificial preserving where the vinegar is used (acetic acid). The high concentration of vinegar in the environment destroys the microorganisms. The moulds and yeasts have a higher resistance to acids and therefore NaCl and sugar are additionally used, and they are possibly supplemented with preservation by pasteurization/sterilization.

- ***Preserving food with chemicals antiseptics*** – the substances which have the property to stop the development and action of some microorganisms (so they have bacteriostatic properties) or they can destroy them (bactericidal properties). The following are used:

- benzoic acid and its salts – they are used to the preservation of black spawns, fruit juices, confectionery products, olives in brine.

- sulphur dioxide, sodium metabisulfite- they are used to the preservation of jams, natural syrups, broth, wine.

- sodium formate – it is used for preserving the fish spawns

- sorbic acid and its salts- they are used for tomato paste, frozen vegetables and fruits, confectionery products.

– ***Modern methods of food preservation***: preservation by radiation, preservation with the help of the magnetic field (static or pulsed), preservation by sterilized filtration (ultrafiltration) for some fruits juices, preservation under the pressure of carbon dioxide (to the preservation of fruits, eggs, meat products and fruits juices, kept in tanks that are hermetically closed) and the preservation with the help of microwaves (it is applied to pasteurisation, sterilisation of the hermetically packaged products, freeze-drying of meat, fish, fruit, drying pasta, fries, carrots, onion, etc.). [10] Some of these have been presented in the UNIT I, pct.1.2.

– ***General aspects of the Hurdle technology***[11] - the stability and microbial safety of most foods are based on a combination of several factors (hurdles) that must not be exceeded by the present microorganisms. This is illustrated by the so-called hurdle effect (hurdle), (Leistner, 1978, Leistner et al., 1981). Leistner and his colleagues have recognized that the hurdle concept illustrates only the fact well-known that complex interactions between temperature, water activity, pH, redox potential, etc. are significant for the microbial stability of the food. From the understanding of the hurdle effect, the hurdle technology (hurdle has been derived), which allows improvements regarding to safety and quality, as well as the economic properties of the food, through an intelligent combination of hurdles (eg. As much water as possible in a product is compatible with his stability) (Leistner 1985; 1987; 1992; 1994). The application of this concept (in the synonym way called combined methods, combined processes, combined preservation, combining techniques, technological barrier or hurdle technology) has been proven successful, because an intelligent combination of hurdles secures the microbial stability and safety, as well as the sensory, nutritional and economic, properties, of a food product.

[9]Dissociation in chemistry and biochemistry is a process in which molecules (or ionic compounds such as salts) are separated or dispersed into smaller particles, atoms, ions or radicals, usually reversibly. http://en.wikipedia.org/wiki/Dissociation_(chemistry)#Acids_in_aqueous_solution

[10] http://proalimente.com/conservarea-alimentelor-metode-conservare-alimentelor/

[11]EUROPEAN COMMISSION, FOOD PRESERVATION BY COMBINED PROCESSES, Final Report, FLAIR Concerted Action No.7, Subgroup, Lothar LEISTNER Federal Centre for Meat Research, GERMANY, Leon G.M. GORRI, Agrotechonological Research Institute (ATO-DLO), THE NETHERLANDS, 1997

Annex 1: Selected A_w values according to https://en.wikipedia.org/wiki/Water_activity

Food		
Substance	**a_w**	**Source**
Distilled Water	1.00	[5]
Tap water	0.99	[citation needed]
Raw meats	0.99	[5]
Milk	0.97	[citation needed]
Juice	0.97	[citation needed]
Salami	0.87	[5]
Cooked **bacon**	< 0.85	[citation needed]
Saturated **NaCl** solution	0.75	[citation needed]
Cereal for breakfast	0.65	[citation needed]
Dried **fruit**	0.60	[5]
Typical indoor air	0.5 - 0.7	[citation needed]
Honey	0.5 - 0.7	[citation needed]
Microorganisms		
Inhibited Microorganism	**a_w**	**Source**
Clostridium botulinum **A, B**	0.97	[citation needed]
Clostridium botulinum **E**	0.97	[citation needed]
Pseudomonas fluorescens	0.97	[citation needed]
Clostridium perfringens	0.95	[citation needed]
Escherichia coli	0.95	[citation needed]
Salmonella	0.93	[6]
Vibrio cholerae	0.95	[citation needed]
Bacillus cereus	0.93	[citation needed]
Listeria monocytogenes	0.92, (0.90 in 30% glycerol)	[7]
Bacillus subtilis	0.91	[citation needed]
Staphylococcus aureus	0.86	[8]
Most molds	0.80	[8]
Microbial development excluded	0.50	[citation needed]

Annex 2: The pH

Tab. 1 The pH level for the development of microorganisms

according to the ,'' Microorganisms and food poisoning – Lifelong learning programme Leonardo da Vinci''

Microorganisms	minimum pH	optimal pH	maximum pH
Mold	1, 5 - 3,5	4, 5 - 6,8	8 - 11
Yeast	1, 5 - 3,5	4 - 6,5	8 - 8,5
Bacteria (allmost)	4,5 - 5,5	6,5 - 7,5	8,5 - 9
Lactic Bacteria	3 - 5	5,5 - 7,5	6,5 - 8

Tab. 2 The approximate level of pH for certain foods

according to the ,'' Microorganisms and food poisoning – Lifelong learning programme Leonardo da Vinci''

Product	pH	Product	pH
Egg white	7,5 - 9	Corn	7 - 7,5
Egg yolk	6,1	Potatoes	5,3 - 5,6
Shells	6,8 - 8,2	Carrots	5,2 - 6,2
Fish (most)	6,3 - 6,8	Onions	5,3 - 5,8
Fresh milk	6,3 - 6,5	Tomatoes	4,2 - 5,8
Butter	6,1 - 6,4	Oranges	3,6 - 4,3
Chicken	6,2 - 6,4	Grapes	3,4 - 4,5
Pork	5,3 - 6,4	Apples	2,9 - 3,3
Beef	5,1 - 6,2	Lemons	1,8 - 2,4

pH limits:

$0 \le pH < 7$ => **acid pH | acid solution**
pH = 7 => **neutral pH | neutral solution**
$7 < pH \le 14$ => **basic pH (alkaline) | basic solution (alkaline)**

More informations about pH - https://ro.wikipedia.org/wiki/PH or https://en.wikipedia.org/wiki/PH

Tab.3 The proportion of non-dissociated acid in percentages for different pH values [13]

Acizi organici **Organic Acids**	Valori pH **pH Values**				
	3	**4**	**5**	**6**	**7**
Acetic acid	98.5	84.5	34.9	5.1	0.54
Benzoic acid	93.5	59.3	12.8	1.44	0.144
Citric acid	53.0	18.9	0.41	0.006	<0.001
Lactic acid	86.6	39.2	6.05	0.64	0.064
Methyl, ethyl, propyl parabens	>99.99	99.99	99.96	99.66	96.72
Propionic acid	98.5	87.6	41.7	6.67	0.71
Sorbic acid	97.4	82.0	30.0	4.1	0.48

Source: Table 7.3 in ICMSF 1980, p 133.

1 [ICMSF] International Commission on Microbiological Specification for Foods. 1980. Microbial ecology of foods. Volume 1, Factors affecting life and death of microorganisms. Orlando: Academic Pr. p 311.

Annex 3. The redox potential

Redox potential Eh for some foods.

FOOD			Presence of air	Eh (mV)	pH
Milk			+	+300 to +340	NR
Cheese	Cheddar		+	+300 to -100	NR
	Dutch		+	-20 to -310	4.9-5.2
	Emmenthal		+	-50 to -200	NR
Butter			-	+290 to +350	6.5
Egg (infertile after 14 d)			+	+500	NR
Meats	Liver raw minced		-	-200	~7
	Muscle	Raw, post-rigor	-	-60 to -150	5.7
		Raw, minced	+	+225	5.9
		Minced, cooked	+	+300	7.5
	Cooked sausages and canned meat			-20 to -150	~6.5
Cereals	Wheat (whole grain)		-	-320 to -360	6.0
	Wheat (germ)		-	-470	NR
	Barley (ground)		+	+225	7
Potato tuber			-	~ -150	~6
Plant juices	Grape		-	+409	3.9
	Lemon		-	+383	2.2
	Pear		-	+436	4.2
	Spinach		-	+74	6.2
Canned foods	"Neutral"		-	-130 to -550	>4.4
	"Acid"		-	-410 to -550	<4.4

* Lemons, avocados and kiwi are classified as very alkaline fruits is and, therefore, are nonacidic. Other neacidic fruits are, bananas, melon, apples, coconut, grape-fruit, grapes, oranges and watermelon.
- NR - No values reported

Taken from: Mossel DAA, Corry JEL, Struijk CB, Baird RM. 1995. Essentials of the microbiology of foods: a textbook for advanced studies. Chichester (England): John Wiley and Sons.