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Food & Beverage Preservation: Practical Guidelines

INTRODUCTION

One of today's challenges for the food industry is to guarantee safe foods throughout the supply chain, whilst retaining the same properties that were present when the foods were freshly made. During the distribution channel, from food manufacturer to consumer, food products need to be protected against physical, chemical and microbial deterioration. This paper focuses on the prevention of food spoilage, caused by the activity of micro-organisms.

MICRO-ORGANISMS

Micro-organisms have many beneficial functions within the food industry. A few examples are yoghurt fermentation by lactobacillus cultures, yeast leavening in bread manufacturing and alcohol production by beer and wine yeast. But micro-organisms are also responsible for food spoilage and some micro-organisms are pathogenic.

In fact the spoilage of the food is caused by the enzymes produced from the micro-organisms, and the removing of the enzymes is achieved most easily by removing the micro-organisms themselves. For growth and multiplication, micro-organisms need organic food (proteins, carbohydrates, fats), a convenient temperature, some moisture, in most cases some air and a suitable pH. Knowledge about the conditions required for growth, will also provide an insight into how to prevent micro-organisms growing and therefore prevent food spoilage.

However, whatever other measures are taken regarding preservation, it is clearly essential that food is processed under the highest and most hygienic conditions in order to minimise the microbial load and minimise any possible contamination.

HURDLE TECHNOLOGY

Hurdle technology means putting up different hurdles or different means of preventing microbial activity and multiplication.

Hurdles in the production process (temperature)
An increase in temperature leads to increased activity of micro-organisms and enzymes. As a rule of thumb, for every increase in temperature of 10 °C, the activity increases two times. This rule is true within the temperature range of 0 to 60 °C.

At temperatures above 60 °C, micro-organisms and enzymes are destroyed or inactivated. Depending on the temperature / time combination applied (pasteurisation, sterilisation, UHT, HTST), part or all micro-organisms are destroyed and enzymes are inactivated. However, it is important to note that heat-resistant species and spores may survive heat treatments.

Decreasing temperatures also reduce the activity of micro-organisms and enzymes. In the refrigerator (4 to 6 °C) and in the freezer (-15 to -20 °C), micro-organisms are less active or completely inactive, but they are not destroyed.

Other physical processes such as hydrostatic pressure, irradiation, ultrasound and pulsed electric fields are potential methods for preservation.

Hurdles in packaging (air / oxygen)
By carefully choosing the packaging material and packaging process (vacuum packaging or modified atmosphere packaging), oxygen as a growth factor can be removed. It should be noted that there are anaerobic micro-organisms which live without oxygen and among these are some food pathogens.

Hurdles in the food composition (pH, Aw, acidulants and preservatives)
As stated above, the highest quality ingredients, with as low as possible microbial count, should be used. Furthermore the food composition itself creates a more or less attractive environment for micro-organisms and makes the food more or less susceptible for food spoilage. Two very important factors are the presence of water and the acidity level of the food.

Water is essential for micro-organisms and therefore drying is an effective method of preservation. Preservation methods, such as the addition of high salt levels and addition of high sugar levels, are based on reducing the water that is available for the micro-organisms. Availability of water can be characterised by the so-called wateractivity (Aw).

Preservation, by influencing the acidity level (pH), is undertaken through the addition of organic acids, e.g. pickling in vinegar.

Last but not least, chemical preservatives can be added to reduce or inhibit the activity of the micro-organisms.

The approach of combining multiple food hurdles in food processing, food packaging and food composition is most effective and will result in lower dosages of preservatives being required.

The remainder of this paper will concentrate on the effects of the food composition: pH, Aw, acidulants and preservatives.

Acidity (pH)

Most micro-organisms grow best around neutral pH (6.6 to 7.5), but some still grow below pH of 4. Growth depends on more factors than just the pH, but as a general guideline, the following ranges can be given:

Moulds can grow between	pH 0 to 11
Yeasts can grow between	pH 2 to 8
Bacteria can grow between	pH 4 and 9

Wateractivity (Aw)

The definition of wateractivity (Aw) is the ratio of the water vapour pressure of a food substrate to the vapour pressure of pure water at the same temperature.

Examples: Aw of pure water is 1.00
Aw of 22% NaCl solution is 0.86

A lower Aw means less available water for the micro-organisms and results in lower activity and decreasing growth. General guidelines for minimum Aw values for growth are as follows:

Bacteria can grow above	Aw 0.90
Yeasts can grow above	Aw 0.88
Moulds can grow above	Aw 0.80

But there are always exceptions. For example, some xerophilic and osmophillic yeasts and moulds can grow at Aw 0.61.

ACIDULANTS AND PRESERVATIVES

Preservatives are added to prevent the growth of unwanted micro-organisms, food spoilers and food pathogens. Acidulants influence the pH and therefore influence the environment of the micro-organisms and also influence the effectiveness of preservatives. The selection and combination of the right acidulant and/or preservative is essential to obtain the best results in shelf life. Several factors which need to be considered are summarised in the following tables.

Range of micro-organisms affected and working pH range

ACIDULANTS	BACTERIA	YEASTS	MOULDS	WORKING PH RANGE
Acetic acid & acetates	++	+	+	3.0 to 5.0
Lactic acid & lactates	+	–	–	3.0 to 7.0

– no effect on the growth of micro-organisms
+ decrease the growth of micro-organism, the more + the bigger the effect

PRESERVATIVES	BACTERIA	YEASTS	MOULDS	WORKING PH RANGE
Benzoic acid & benzoates	++	+++	++	2.5 to 4.0
Sorbic acid & sorbates	+	+++	+++	3.0 to 6.5
Propionic acid & propionates	+	–	+++	2.5 to 5.5
Sulfur dioxide, sulfite, metabisulfite	+	++	++	2.5 to 5.0

– no effect on the growth of micro-organisms
+ decrease the growth of micro-organism, the more + the bigger the effect

Mode of action: dissociate, pH, pKa
When considering how acidulants and preservatives function, it is important to distinguish between the pH of the food (external pH) and the so-called “weak acid effect”, which influences the pH of the micro-organism cell (cytoplasm pH).

Food spoilers and food poisoners grow between pH 4 to 8. Microbial growth can be limited by lowering the pH of a food and by adding acidulants such as acetic, citric and lactic acid. However, acidification alone may require a too low pH value for the food to maintain an acceptable taste.

More important than the external pH is the pH within the micro-organism cell, the cytoplasm pH. To influence the cytoplasm pH the acid needs to enter the cell. Strong acids which are dissociated in H+ and anion do not pass the phospholipid cell membrane easily. But weak acids such as benzoic and sorbic are lipid soluble and enter through the cell membrane into the cytoplasm by simple diffusion of the undissociated acid.

The pH of the cytoplasm is close to neutral, which means that inside the cell the weak acid will dissociate into H+ and anion. The anions will accumulate in the cell and the H+ protons will absorb the buffering capacity and eventually decrease the cytoplasm pH, which results in bacteriostatic or bacteriocidal effects.

Essential for the weak acid effect is the presence of undissociated weak acid in the external medium, meaning that the external pH of the food is preferably below the pKa value of the preservative.

The above is applicable for sorbic, benzoic, propionic, acetic and lactic acid.

ACIDULANTS	pKa
Acetic acid	4.75
Lactic acid	3.86
Citric acid	3.14

PRESERVATIVES	pKa
Benzoic acid	4.20
Sorbic acid	4.76
Propionic acid	4.87

Example acetic acid:

$$\text{HAc} \rightleftharpoons \text{H}^+ + \text{Ac}^-$$

The undissociated (HAc) and dissociated form (H+ and Ac-) are in equilibrium.
When the pH = pKa, 50% of the acid is dissociated and 50% of the acid is undissociated.
When pH is lower than pKa, the majority is in undissociated form,
which can transfer into the micro-organism cell.

The table below makes the influence of pH/pKa very clear. It is important to note that citric acid does not have important antimicrobial benefits, since to deliver an antimicrobial effect, a too low pH is needed and the taste will be influenced considerably.

pH	ACETIC ACID	LACTIC ACID	CITRIC ACID
2.9	–	–	–
3.0	–	–	–
3.7	–	+	+
4.0	+	+	+
MIC % w/w	0.84%	0.67%	2.49%

– no / delayed growth of micro-organisms
\+ growth of micro-organisms
MIC = minimum inhibitory concentration, Lactobacillus brevis

Other chemical and physical properties

ACIDULANTS	E NUMBER	SOLUBILITY [1]	APPEARANCE [2]	OTHER REMARKS
Acetic acid	E260	+++	liquid	Intense acid flavour
Sodium acetate	E261i	++	solid	
Sodium diacetate	E262ii	++	solid	Sodium diacetate is called "dry acetic acid". It supplies free acetic acid in a solid form (approx. 40%)
Citric acid	E330	+++	solid	Acid taste with fruity character
Lactic acid	E270	+++	liquid [3]	Mild acid taste
Sodium lactate	E325	+++	liquid + solid	Slightly salty
Potassium lactate	E326	+++	liquid [3]	Potassium salt can be used when sodium reduction is an issue

PRESERVATIVES	E NUMBER	SOLUBILITY [1]	APPEARANCE [2]	OTHER REMARKS
Benzoic acid	E210	+	solid	Sweet, astringent taste
Sodium benzoate	E211	++	solid	
Potassium benzoate	E212	++	solid	Potassium salt can be used when sodium reduction is an issue
Sorbic acid	E200	+	solid	Neutral taste and odour
Potassium sorbate	E202	++	solid	Potassium salt is the most widely used form
Propionic acid	E280	+++	liquid	
Sodium propionate	E281	+++	solid	
Calcium propionate	E282	++	solid	Calcium propionate is the most widely used form

PRESERVATIVES	E NUMBER	SOLUBILITY [1]	APPEARANCE [2]	OTHER REMARKS
Sodium sulphite	E221	++	solid	% SO2 = 51%
Sodium hydrogen sulphite	E222	++	solid	% SO2 = 62%
Sodium metabisulphite	E223	++	solid	% SO2 = 67%
Potassium metabisulphite	E224	++	solid	% SO2 = 58%

[1] Solubility: +++ soluble in all proportions, ++ very soluble, + sparingly soluble
[2] Appearance, for the solid materials the particle size is important, see below
[3] Lactic: the basic products are liquids, but dry powders on carriers are available in the market.

Solubility
Water solubility is very important since only dissolved material is active against micro-organisms. The low solubility of benzoic acid and sorbic acid is the reason that these two products are not commonly used in the food industry and their salts are preferred.

Particle size
For the solid materials the particle size is important. In many cases products are offered with different particle sizes, these are identified as powder, crystal, granulate or agglomerate.

Powders are applied when a smaller particle size is needed and when the product is blended with other dry ingredients such as flour in bakery products. If available, non dusting powders are preferred.

For applications where the products needs to be dissolved in a liquid (beverages, brines), a good dispersibility and flowability is important. Crystals, agglomerates or granulates impart these properties and are more easy to dissolve compared to powders.

CLEAN LABEL

Clean label refers to the trend of food manufacturers striving to simplify ingredient listing, as consumers are demanding labels with ingredients they recognise and understand. As "no preservatives" is amongst the most popular clean label claims, food ingredient manufacturers have developed new ingredients to meet this demand. Several solutions are already offered in the market, and these make use of the oldest traditions in food manufacturing like maturing, enzymolise and fermentation to produce cultured products.

Some examples of this oldest method of preservation are fermented products such as yoghurt, cheese, fermented sausages and 'sauerkraut'. All these fermented products have a longer shelf life than their original food (milk, meat and cabbage). From fermentation processes, several components such as organic acids, sugars, peptides and other metabolites are formed, which have a positive effect on the taste, the shelf life and food safety, as well as texture. By choosing the right substrate and selecting the optimal culture, a ferment can be produced to fit the desired functionality. This ferment can be added to the food, producing safe, flavourful products, with an acceptable shelf life.

APPLICATIONS AND DOSAGES

In the following paragraphs some short guidelines with regard to applications and dosages are given. Please note the following:

- Ingredient manufacturers perform studies to determine anti-microbial activity, but not all applications and not all species of different micro-organisms can be tested.
- Other food ingredients might influence the performance of preservatives. For example, proteins and fibers can bind with anti-microbial agents and therefore decrease the effectiveness of preservatives.
- The most current regulatory updates applicable to you should always be checked to ensure full compliance regarding application and maximum dosage. As an example, the following tables consider EU regulations only. Please check carefully the regulations applicable for you.

In all cases microbial stability trials are recommended to confirm the optimal dosage in your application or for your specific spoilage and/or pathogenic micro-organisms.

Recommended and typical dosages from different literature sources show a wide spread and are sometimes exceeding the maximum dosage limits within the EU regulations. Therefore, within the below tables, either the maximum dosages following the EU regulations or recommended dosages when the EU regulations states "quantum satis", are given. Please also refer to the below section - regulatory.

BAKERY

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Pre-packed, sliced bread and rye bread. Partially baked, pre-packed bread	Ca propionate Na propionate		1000 to 3000 mg/kg expressed as propionic acid
Pre-packed fine bakery wares with Aw > 0.65	Ca propionate Na propionate		2000 mg/kg expressed as propionic acid
Pre-packed, sliced bread and rye bread	Sorbic, sorbates		2000 mg/kg
Fine bakery wares with Aw > 0.65	Sorbic, sorbates		2000 mg/kg
Bread	Sodium diacetate	0.1 – 0.4% for white and wheat bread. In rye bread slightly higher dosages of 0.6 to 0.7% are applied	Quantum satis

REMARKS
- Calcium propionate is the preferred product for yeast leavened bakery products. Propionates will slightly reduce the yeast activity, which can result in a slight reduction in bread volume. This can be solved by increasing the yeast dosage.
- In chemically leavened bakery products (containing baking powder), such as cakes, sodium propionate is the preferred product. Calcium propionate is not used since calcium can interfere with the leavening action.
- Sorbates are effective yeast inhibitors and are therefore not recommended for use in yeast leavened bakery products.
- In baked goods propionates and sorbates are recommended to be used together as they show synergistic effect. Recommended dosage to start testing: 0.1% w/w and observe product during shelf life.
- Sodium diacetate shows a synergistic anti-microbial effect with calcium propionate in bread applications.

BEVERAGES

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Non alcoholic flavoured drinks*	Sorbic, sorbates		300 mg/litre
Non alcoholic flavoured drinks*	Benzoic, benzoates		150 mg/litre
Non alcoholic flavoured drinks*	Combination of sorbates + benzoates		sorbic/sorbates 250 mg/litre + benzoic/benzoates 150 mg/litre
Spirits with < 15% alc.	Sorbic, sorbates		200 mg/litre
Spirits with < 15% alc.	Benzoic, benzoates		200 mg/litre

*) excluding dairy based drinks

REMARKS
- Juices and non carbonated beverages require a slightly higher dosage than carbonated beverages.
- Wine: Always refer to specific regulations regarding wine processing.

CONVENIENCE FOOD

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Sauces and dressings	Lactic acid	0.05 – 0.2%	Quantum satis
Sauces and dressings	Acetic acid (100%) or vinegar (12%)	0.2 – 0.4 % (acetic acid)\ 2 – 3% (vinegar)	Quantum satis
Sauces and dressings	Ferment	Up to 1.5%	Quantum satis
Emulsified sauces (>60% fat)	Sorbic, sorbates		1000 mg/kg
Emulsified sauces (>60% fat)	Benzoic, benzoates		500 mg/kg
Emulsified sauces (>60% fat)	Combination of sorbates + benzoates		1000 mg/kg
Emulsified sauces (<60% fat)	Sorbic, sorbates		2000 mg/kg
Emulsified sauces (<60% fat)	Benzoic, benzoates		1000 mg/kg
Emulsified sauces (<60% fat)	Combination of sorbates + benzoates		2000 mg/kg
Non emulsified sauces	Combination of sorbates + benzoates		1000 mg/kg
Prepared salads	Combination of sorbates + benzoates		1500 mg/kg
Prepared meals and salads	Ferment	Up to 1.5%	Quantum satis
Liquid soups & broths (not canned)	Combination sorbates + benzoates		500 mg/kg
Soups	Ferment	Up to 1.5%	Quantum satis

REMARKS

- Benzoates: please note the relative low working pH: below 4.5.
- Potassium sorbate and sodium benzoate as a combination is beneficial, since a broad spectrum of effectiveness is created.
- Lactic acid has a mild acid taste in comparison with other acidulants. Combinations of lactic acid and acetic acid (or vinegar) are common to reach the required pH value as well as required flavour profile.
- Ferment: additional benefit is flavour enhancement of salty and savoury notes.

FRUIT (JAMS, MARAMALADES, FRUIT PREPARATIONS)

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Low and no sugar jams, marmalades and other fruit based spreads	Benzoic, benzoates		500 mg/kg
Low and no sugar jams, marmalades and other fruit based spreads	Combination of sorbates + benzoates		1000 mg/kg
Jams, marmalades and other fruit spreads, including low calorie products	Sulfites		50 mg/kg expressed as SO2. 100 mg/kg if made with sulphited fruit
Fruit and vegetable preparations	Sorbic, sorbates		1000 mg/kg
Fruit based pie-fillings	Sulfites		100 mg/kg expressed as SO2
Dried fruit	Sorbic, sorbates		1000 mg/kg
Dried fruit	Sulfites		200 – 2000 mg/kg expressed as SO2
Candied fruit	Combination of sorbates + benzoates		1000 mg/kg
Candied fruit	Sulfites		100 mg/kg expressed as SO2

DAIRY

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Processed cheese	Sorbic, sorbates		2000 mg/kg
Unripened cheese	Sorbic, sorbates		1000 mg/kg
Pre-packed, sliced cheese	Sorbic, sorbates		1000 mg/kg

MEAT, POULTRY, FISH

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Processed meat and poultry	Lactates	2 – 4.5%	Quantum satis
Processed meat and poultry	Combination of lactates + (di)acetates	1 – 4 %	Quantum satis
Processed meat and poultry	Ferment	1 – 3.5 %	Quantum satis
Pre-packed preparations of fresh minced meat	Lactates and acetates	1 – 4 %	Quantum satis (following 2010/69/EC)
Crustaceans and cephalopods (fresh, frozen, deep frozen, cooked)	Sulfites		50 – 300 mg/kg expressed as SO2
Semi-preserved fish and fisheries products including crustaceans, mollucsc, surimi and fish/crustacean paste; cooked crustaceans and mollucsc	Combination of sorbates + benzoates		2000 mg/kg

REMARKS

- Lactates are commonly used in meat and poultry products to extend the shelf life. Additional benefits are enhanced flavour and improved slice-ability. Lactates can replace part of the sodium chloride in the formulation.
- The combination of lactates and acetate is effective against pathogenic bacteria without having a negative effect on taste or texture.
- Additional benefit of ferments is the flavour profile. Specific products to achieve additional salt reduction are developed.

FATS AND OILS

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Fat emulsions (>60% fat), excluding butter	Sorbic, sorbates		1000 mg/kg
Fat emulsions (<60% fat)	Sorbic, sorbates		2000 mg/kg

OTHER APPLICATIONS

APPLICATION	PRODUCT	RECOMMENDED DOSAGE	MAXIMUM DOSAGE FOLLOWING EC/1333/2008
Liquid egg (white, yolk, whole egg)	Combination of sorbates + benzoates		5000 mg/kg or mg/litre
Dehydrated, concentrated and frozen egg products	Sorbic, sorbates		1000 mg/kg or mg/litre
Dehydrated potatoes	Sulfites		400 mg/kg expressed as SO2
Processed potatoes (including frozen)	Sulfites		100 mg/kg expressed as SO2
Potato dough and pre-fried potato slices	Sorbic, sorbates		2000 mg/kg
White vegetables, processed (including frozen)	Sulfites		50 mg/kg expressed as SO2
Processed mushrooms (including frozen)	Sulfites		50 mg/kg expressed as SO2
Batters	Sorbic, sorbates		2000 mg/kg or mg/litre

REMARKS

- Sulphites are multifunctional additives: preservation, anti-oxidant and colour stabilisation (prevent enzymatic and maillard browning).

REGULATORY

Acidulants and preservatives are food additives and their use is subject to several laws and regulations. For the member states of the European Union, their use is subject to Regulation (EC) No 1333/2008 on food additives, published in December 2008.

Annex I of this Regulation describes the functional classes of food additives:
“preservatives” are substances which prolong the shelf life of foods by protecting them against deterioration caused by micro-organisms and/or which protect against growth of pathogenic micro-organisms.

“acids” are substances which increase the acidity of a foodstuff and/or impart a sour taste to it.

“acidity regulators” are substances which alter or control the acidity or alkalinity of a foodstuff.

Annex II provides the community list of food additives approved for use in foods
The list is published in November 2011, in Commission Regulation (EU) No 1129/2011 amending Annex II to Regulation (EC) No 1333/2008.

The list includes:

- The name of the food additives and the E numbers (part B)
- Definitions of groups of additives (part C)
- The foods to which the food additives may be added, food categories (part D)
- The conditions under which the food additives may be used (part E)

Part C. Acetic acid and acetates, lactic acid and lactates as well as citric acid are in group 1, and can be used following quantum satis principle. Quantum satis means that there is no maximum dosage defined, but the addition should be at a level not higher than necessary. In practice the maximum level is determined by taste.

Part C. Sorbic acid and sorbates, benzoic acid and benzoates, propionic acid and propionates as well as the sulphites are in the Group: Other additives that may be regulated combined.

For exact approved use and dosage part E of the regulation must be consulted.

Specifications of food additives
Commission Regulation (EU) No 231/2012, published in March 2012, provides the specifications, such as purity criteria, origin and other necessary information, for food additives.

In the applications section some of the approved uses are summarised. For the complete list and exact approved applications, dosage and conditions of use in the European Union, the most current Regulations and directives must be checked. The complete texts as well as consolidated versions with last updates can be viewed and downloaded from the website: http://eur-lex.europa.eu/en/index.htm

For any use outside the European Union, please check carefully the laws and regulations applicable for you. Please keep in mind that you are responsible for compliance with any applicable legal and regulatory requirements.

CONTACT US

Brenntag Europe is delighted to offer its customers a wide portfolio of preservatives and acidulants. If you would like to discuss with one of our food dedicated specialists, which particular products would best meet your requirements, then please write a short email to food-emea@brenntag.de and your local Brenntag office will provide you with the requested information and samples.

Please visit **www.brenntag-food.eu**

Information Sources:

Modern Food Microbiology, 7th Edition, Jay, Loessner, Golden
Food Preservatives, 2nd edition, Russell, Gould
Brochures and websites of our suppliers

Brenntag Holding GmbH
Stinnes-Platz 1
45472 Mülheim an der Ruhr
Germany
Phone: +49 208 7828-7015
food-emea@brenntag.de