Technical Information Sheet
Processing Aids

prepared for

The Brewers of Europe

by

Campden BRI

Compiled by

E Denise Baxter,
August, 2014.

Contents

Page

List of abbreviations **3**

Part 1. Non-technical Summary **4**

Part 2. Technical Summary **5**

Part 3. Technical Data **6**
1. Background: **6**
1.1 What are processing aids?
1.2 Categories of processing aids

2. Legislation **8**
2.1 EU legislation
2.2 National legislation in EU Member States
2.3 WHO standards

3. Specific processing aids **13**
3.1 Antifoams 13
3.2 Enzymes 15
3.3 Finings/clarifying aids 15
3.4 Filtration aids 23
3.5 pH regulators 28
3.6 Yeast 37
3.7 Yeast cleansing agents 39
3.8 Yeast nutrients 42

NB: The list of processing aids provided by The Brewers of Europe to CampdenBRI in 2012 has been used for selection of processing aids to be included in this TIS. Water treatment salts are not covered since they are the subject of a separate TIS on Water Treatment Agents.

4. HACCP for use of processing aids **46**

5. References **48**

Part 4. Frequently Asked Questions **60**

Tables.

Table 1. Overview of national legislation on processing aids in Europe **9**
Table 2. Enzymes allowed in beer and brewing in France *(France, 2013)* **11**
Table 3. Processing aids allowed in brewing in France **12**
Table 4. EU Purity criteria for pH regulators **28**

Abbreviations

A. - *Aspergillus*
ADI – Acceptable Daily Intake
AFC – EFSA Panel on Food Additives, Flavourings, Processing Aids and Materials in Contact with Foods
AFSSA - Agence Française de Sécurité Sanitaire des Aliments (France)
B. – *Bacillus*
BFBi – Brewing, Food and Beverage Industry Suppliers Association
CAC – Codex Alimentarius, Committee on Food Additives and Contaminants
CFR – Code of Federal Regulations (US)
COT- Committee on Toxicity (UK)
DG-HCP – Directorate General of Health and Consumer Protection
DMPS - dimethylpolysiloxane
EC – European Commission
EFSA – European Food Safety Authority (EU)
EINECS - European Inventory of Existing Chemical Substances
EU – European Union
FAO - Food and Agriculture Organization of the United Nations
FCC – Food Chemicals Codex
FDA – Food and Drug Administration (US)
FIC – EU labelling legislation "Food Information for Consumers"
FSANZ – Food Standards Australia New Zealand
GM – genetically modified
GRAS – Generally Recognised as Safe
JECFA - Joint FAO/WHO Expert Committee on Food Additives
MTDI – Maximum Tolerable Daily Intake
NAD(H) – nicotinamide adenine dinucleotide (reduced)
NO(A)EL – No Observed (Adverse) Effect level
NRV – Nutrient Reference Value
NTP – National Toxicity Programme (US)
OECD- Organisation for Economic Cooperation and Development
PVPP - polyvinylpolypyrollidone
QPS – Qualified Presumption of Safety (EU)
qv – which see
REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals (EU).
SCF – Scientific Committee for Food (EU)
SCOGS – Select Committee on GRAS substances (US)
SEM - semicarbazide
SIDS- Screening Information Dataset (chemical assessment profiles generated by OECD members)
TDI – Tolerable Daily Intake (see also ADI)
TTB – Alcohol and Tobacco Tax and Trade Bureau (US)
WHO - World Health Organisation

Part 1. Non-technical Summary

- Processing aids have been used in the manufacture of beer for centuries and are important for producing beer of the type, quality and value demanded in today's market.
- Processing aids are substances which may be used to perform a specific function during the manufacture of a food or beverage. They are often, but not always, removed during further processing. They differ from food additives in that they have no function in the final product.
- Unlike food additives, processing aids do not need to be declared on the label unless they are made with or from listed allergens. Isinglass, which is used to clarify beer and is made from the swim bladders of fish (which is a listed allergen) are exempt from making an allergen declaration because clinical trials have demonstrated that it is not allergenic at the doses used.
- Many of the processing aids which may be used in brewing are used as additives in other foods. These include, for example, many of the mineral salts used in brewing as pH regulators.
- A major group of processing aids used in brewing are food enzymes. These are used especially in mashing to assist in the conversion of malt to produce sugar which can be fermented by yeast.
- Yeast itself is also classed as a processing aid for most beers. Although yeast performs an essential function in fermenting sugar to form alcohol during the production of beer, it has no function in the final beer and is removed prior to packaging. However, a few specific beer types undergo a second fermentation in the package and still contain active yeast. In these latter cases, the yeast would be classified as a characterising ingredient which would have to be included in the ingredient list, if any.
- Another important group of processing aids used in brewing are filtration aids. These are generally inert materials which are used to remove particles of yeast or protein which make the beer cloudy unless they are removed.
- Processing aids must conform to EU legislation on materials in contact with food. This means that they must be safe in use and must conform to any relevant purity specifications, for example, those set for food additives.
- There is no specific legislation governing processing aids at EU level. Since many substances used as processing aids in brewing are authorised in the EU as additives for other foods, purity criteria have been specified in EU legislation. Processing aids must also conform to EU legislation on materials in contact with food.
- Some EU countries do not accept the use of certain processing aids.

Part 2. Technical Summary

- Processing aids have been used in the manufacture of beer for centuries and are important for producing beer of the type, quality and value demanded in today's market.
- Processing aids are substances which may be used to perform a specific function during the manufacture of a food or beverage. They differ from food additives in that they have no technological function in the final product.
- Processing aids which are used to help filtration are generally inert materials such as kieselguhr or PVPP which are completely removed from the beer stream, leaving little or no residues.
- Other processing aids, such as pH regulators, are mineral salts which are ionised in solution and exist in beer as ions identical to those derived from the raw materials, including malt and water.
- Unlike food additives, processing aids do not need to be declared on the label unless they are made with or from listed allergens. Isinglass, used to clarify beer and made from the swim bladders of fish (which is a listed allergen) is exempt from making an allergen declaration because clinical trials have demonstrated that it is not allergenic.
- Many of the processing aids which may be used in brewing are used as additives in other foods. These include, for example, many of the mineral salts used as pH regulators.
- A major group of processing aids used in brewing are food enzymes. These are used especially in mashing to assist in the breakdown of protein, carbohydrate and cell walls in malt. Use of these enzymes improves the rate and efficiency of mash separation and also increases the supply of fermentable sugar.
- Yeast is classed as a processing aid rather than an ingredient for most beers. Although yeast performs an essential function in fermenting sugar to form alcohol during the production of beer, it has no function in the final beer and is removed prior to packaging. However, a few specific beer types undergo a second fermentation in the package and still contain active yeast.
- Another important group of processing aids used in brewing are filtration aids. These are generally inert materials which are used to remove particles of yeast or protein which make the beer cloudy unless they are removed.
- Processing aids must conform to EU legislation on materials in contact with food. This means that they must be safe in use and must conform to any relevant purity specifications, for example, those set for food additives.
- There is no specific legislation governing processing aids at EU level. Since many substances used as processing aids in brewing are authorised in the EU as additives for other foods, purity criteria have been specified in EU legislation.
- Some EU countries do not accept the use of certain processing aids.

Part 3. Technical Data

1. Background

1.1 What are processing aids?

Processing aids are defined in EU legislation as substances which are not consumed as foods but are intentionally used in the processing of raw materials, foods or their ingredients, to fulfil a certain technological purpose during treatment or processing. They may result in the unintentional but technically unavoidable presence in the final product of residues of the substance or its derivatives provided they do not present any health risk and do not have any technological effect on the final product *(EU, 2008c).*

Many substances which are used in brewing as processing aids are also authorised as food additives for foods other than beer.

Processing aids may also contain other substances (additives) such as carriers and preservatives. Wherever possible, these should conform to the list of additives authorised in the EU for use in food additives, flavourings and enzymes *(EU, 2008c).* If other substances are used, it is the responsibility of the manufacturer to ensure that they are safe in use. The amount of additives used in processing aids must not be sufficient to have a technological effect in the final beer.

1.2 Categories of processing aids

The main categories of processing aids used in brewing are:

- **Antifoams:** These are used mainly in fermenting vessels to prevent excess foaming and consequent loss of foam-positive proteins which are required to sustain foam in the final beer. Antifoams may also be used in the kettle, where excess foaming can lead to a loss of hop acids. Small quantities can be used during yeast propagation, where the need for agitation can cause foaming. Waste systems, which can contain a lot of protein from trub, yeast and waste beer, may also benefit from the use of antifoams *(Johnson, 2009).* Most brewing antifoams are silicone - based, but recently a product based on hops has become commercially available *(Botanix & Marriott, 2008)*

- **Enzymes:** Single enzyme preparations or enzyme mixtures may be used during mashing, fermentation or maturation. Most enzymes used in brewing are cytolytic, amylolytic or proteolytic, and are used to supplement the natural enzyme activity in the malt (for example, in high adjunct brews). Enzymes may also be used to provide an enzymic activity which is not naturally present in brewing raw materials. Examples include the use of dextrinases such as pullulanase to increase the supply of fermentable sugars, thus increasing final attenuation, and the use of acetolactate decarboxylase to prevent the formation of diacetyl off-flavours in the beer *(Aschengreen & Jepsen, 1992: Bamforth, 2008).* More detailed information about brewing enzymes can be found in the Enzymes TIS.

- **Finings/clarifying aids:** These substances can be used towards the end of wort boiling, to improve the clarity of the wort, or after fermentation and maturation, to clarify the beer. They act by combining with haze forming materials such as proteins, causing them to form large flocs which precipitate out of solution and can be removed.

- **Filtration aids:** Filtration aids act by physical means, by which particles of yeast or protein are trapped by the filter and removed from the liquid stream. Some filter aids are composed of an inert material containing many pores which trap particles by size. Other types of filter have a fibrous structure.

- **pH regulators:** A variety of mineral salts (brewing salts) are used to adjust the pH of the brewing water, depending upon natural water quality and the type of beer being brewed. They can also have other effects, for example on enzyme activity and beer flavour. Brewing salts are dealt with in more detail in the Water Treatment Agents TIS.
  The many biological processes which occur during brewing each have their own optimum pH. For example, the optimal value for α-amylase is 5.7, whilst that of β-amylase is much lower, at 4.2. The pH optima for proteases range from 4.2 – 5.0. Thus brewers generally aim for a mash pH around 5.2 - 5.3. The effect of water treatments can mean that mash pH may be at the higher end of this range *(Englmann & Reichert, 1991)* therefore pH regulators may be used to adjust the pH of the mash. They may also be added towards the end of mashing, to adjust the pH to the optimum for mash filtration, during wort boiling to assist protein precipitation, or to the cooled wort prior to fermentation. Several organic or inorganic acids and occasionally also inorganic bases may be used. In general, acidification of wort increases amylolytic activity and raises the concentration of soluble nitrogen in the wort *(Gresser, 1992),* whilst raising the pH increases bitterness *(Methner et al, 2013)* and reduces the extent of proteolytic activity in the mash. Mash acidification usually has little effect on final beer pH, since it also increases the buffering capacity of the wort.
  Added acids and alkalis are ionised in wort and will react with other ions in solution, sometimes forming compounds which will be precipitated out and lost in subsequent brewing stages (for example, in hot and cold breaks). Other ions will be taken up by the yeast. Others may be modified by the yeast during fermentation. Thus substances added as pH regulators do not retain their identity during the brewing process and any ions which persist into beer are undistinguishable from those derived from other sources such as brewing liquor, malt, hops and yeast.
  The practice of adding organic or mineral acids to wort is generally not allowed for beers brewed according to the Reinheitsgebot, where only biological acidification (using bacteria such as lactic acid bacteria which produce organic acids naturally) is allowed.

- **Yeast:** Yeast is a unicellular micro-organism and belongs to the kingdom of Fungi. It is essential in brewing, as it ferments sugars, converting them to alcohol. Most brewing yeasts are classified as *Saccharomyces cerevisiae* or *S. pasteorianus* but there are many different strains which vary slightly in their characteristics, such as in production of flavour compounds and flocculation habit. Other yeasts such as the *Brettanomyces (Dekkera)* are used to produce certain beers.

- **Yeast cleansing agents:** Since yeast may be re-used several times, it is often "washed" with dilute acid in order to remove any contaminating .nisms (such as bacteria with nitrate-reducing activity, which can trigger the formation of N-nitroso compounds in the beer). Phosphoric or sulphuric acids are most commonly used. Nitric acid should NOT be used, since this can contribute to the formation of N-nitroso compounds.

- **Yeast nutrients:** Yeast requires an adequate supply of nutrients, including amino acids, salts and vitamins, to fuel its growth during fermentation. An adequate supply of nutrients is particularly important for a balanced synthesis of lipids in yeast cells *(Ohno & Takahashi, 1986).* Nutrients are normally supplied by the malted barley but in some cases these can be insufficient, and additional yeast nutrients must be added to the fermenting wort. Additional nutrients can also be required when fermenting high gravity worts *(Gibson, 2011).* In addition to the use of individual mineral salts, such as zinc salts, a number of different commercial formulations are available. Most contain amino acids and/or simple nitrogen compounds such as ammonium sulphate as well as inorganic salts: vitamins may also be included. Urea should NOT be used as a yeast nutrient, since it can trigger the formation of the carcinogen ethyl carbamate during fermentation.

2. Legislation

2.1 EU legislation

Unlike food additives, processing aids, with the exception of food enzymes (see below, also The Brewers of Europe TIS on Brewing Enzymes) are NOT currently regulated at EU level. The safety in use of processing aids is covered by EU Materials in Contact with Food legislation *(EU, 2004).* This framework regulation requires that materials which are intended to come into contact with food are safe and do not transfer any of their components into that food in quantities which could endanger human health, change the composition of the food in an unacceptable way, or adversely affect its taste or odour. Such materials must be manufactured according to Good Manufacturing Practice and must be traceable throughout the production chain.

Processing aids are also covered by the general principles of food law as laid down in Regulation 178/2002 *(EU, 2002).* These include requirements for safety and traceability as well as the prevention of fraudulent or deceptive practices and the adulteration of food.

A few EU countries have legislation which specifically permits (or forbids) the use of specific processing aids in brewing (see 2.2 National legislation). In most EU countries, however, it is the responsibility of the brewer to ensure that any material he uses as a processing aid is safe for consumers and for does not adversely affect the quality of the final product.

Purity criteria for processing aids: Since many of the processing aids used in brewing are authorised in the EU as additives for other foods, purity criteria are specified in EU regulation 231/2012 *(EU, 2012)*, and these can be used to assess the acceptability of a particular processing aid with regards to food safety. For processing aids not

listed in EU additives legislation, purity criteria set down by the WHO or the Food Chemicals Codex can be used (See Part 2.3 WHO and other international standards).

Labelling of processing aids: Processing aids and additives used as processing aids are not required to be declared on the label unless they are made with or from an allergen listed in Annex 2 of the Food Information for consumers (FIC) regulations *(EU, 2011b).* Isinglass and fish gelatine used for clarification in brewing are exempt from allergen labelling.

Food enzymes: EU framework legislation on food enzymes was established in 2008. Regulation 1331/2008 establishes a common framework for the approval of food additives, enzymes and flavourings *(EU, 2008a)*. Regulation 1332/2008 allows for a community list of approved food enzymes *(EU, 2008b).* Industry has been given from September 2011 to March 2015 to provide the Commission with the required information. Until the EU list is drawn up, national rules on the use and marketing of food enzymes and foodstuffs prepared using food enzymes will apply.

REACH is EU legislation concerning the Registration, Evaluation, Authorisation and Restriction of chemicals. It does not generally apply to chemicals which are already covered by more specific legislation, such as food chemicals. However, some manufacturers of food chemicals have pre-registered their products as a precautionary measure. This is noted in the "Specific Legislation section.

2.2 National legislation

As well as conforming to EU legislation on labelling requirements for additives and processing aids, some EU countries have specific legislation on processing aids, or on particular groups of processing aids such as enzymes. An overview is shown in Table 1.

Table 1. Overview of national legislation on processing aids in Europe

Country	Legislation
Austria	No specific legislation on processing aids other than implementation of EU law. The Austrian Codex Alimentarius allows the use of processing aids (undefined other than as clarifying agents) in beer provided they are not hazardous to health and are removed as far as is technically feasible *(Austria, 2013).*
Belgium	No specific legislation on processing aids other than implementation of EU law *(EU, 2008c).* However, following incidents of dioxin contamination, the Belgian Scientific Committee for Food reviewed materials in contact with food (including processing aids) and recommended that manufacturers should conduct a HACCP-type analysis and that customers should carry out a risk assessment *(Belgium, 2011).*
Bulgaria	No specific legislation therefore no restrictions *(Bulgaria, 2000)*
Cyprus	No specific legislation other than general safety and labelling requirements as in EU law *(Cyprus)*
Czech Rep.	No specific legislation other than general EU requirements. No mention of processing aids in Decree No. 335/1997 which gives standards for beer production *(Czech, 1997).*

Table 1. Overview of national legislation on processing aids in Europe continued

Country	Legislation
Denmark	No specific legislation other than general safety and labelling requirements as in EU law *(Denmark, 2005).* Enzyme producers must apply for authorisation for individual enzymes
Finland	No specific legislation other than general safety and labelling requirements as in EU law *(Finland, 2011)*
France	Positive list for beer: enzymes: filtration and clarification aids: pH regulators (see Tables 3 & 4). *(France, 2011, 2014).* Purity criteria are also set.
Germany	Allowed processing aids limited to clarifying aids which work in a mechanical way (eg kieselguhr): lactobacilli: yeast *(Germany, 1974)*
Greece	Positive list *(Greece)*
Hungary	Positive list for beer: Gases (nitrogen and carbon dioxide), yeast, filtering and clarifying agents and enzymes *(CAHG).*
Ireland	No specific legislation so no restrictions. General safety and labelling requirements as in EU law *(Ireland, 2013)*
Italy	Positive list of processing aids allowed in food additives *(Italy, 1996)* http://www.legapesca.coop/Documenti/qualita/DM_27_02_96_209_Disciplina_additivi_alimentari.pdf Tannic acid is specifically allowed as a processing aid in beer *(Italy, 1994)*. http://www.ismea.it/flex/AppData/Redational/Normative/20020520000100278.pdf Brewing salts are also allowed: http://www.mondobirra.org/argoacqua.htm
Lithuania	Positive list for brewing: enzymes (inactivated so prior to pasteurisation): gases (CO_2, N_2, O_2): filter aids: finings (if completely removed from beer and do not affect flavour): pH regulators (lactic acid, $CaCl_2$, $CaSO_4$): stabilisers: zinc salts.
Luxemburg	Luxembourg does not have specific legislation on processing aids. A Grand Ducal regulation relating to beer does not mention processing aids *(Luxembourg, 1994).*
Malta	No specific legislation so no restrictions
Netherlands	No specific legislation: No positive list of processing aids
Norway	No restrictions except that must be safe in use
Poland	No specific legislation: no positive list of processing aids.
Portugal	Positive list: Clarifiers (diatomataceous earths, perlites, activated charcoal, cellulose, carrageenan), colloidal stabilizers (PVPP, silica gel, tannins, proteases) and enzymes (amylases, proteases, glucanases) all at *quantum satis (Portugal, 1996).*
Romania	No national legislation on processing aids for foodstuffs in general or for beer.
Slovakia	Positive list for brewing: H_3PO_4 (pH regulator), up to 600mg/kg: filtration aids (diatomaceous earth, perlites) *(Slovak Rep., 2014).* Many acids, alkalis and salts are also allowed for general use, but not to slow down or speed up the brewing process *(Slovak Rep. 2008).*

Table 1. Overview of national legislation on processing aids in Europe continued

Country	Legislation
Slovenia	No specific legislation on processing aids other than definitions as set out in EU legislation *(Slovenia, 2004).*
Spain	Positive list for foodstuffs: activated carbon: albumin: alginate; bentonite; casein; cellulose: enzymes (positive list): jelly: keratin: kieselguhr: polyamide: PVPP (insoluble): silicon dioxide: tannin *Spain, 1983)* use of filter aids specifically permitted *(Spain,1995)*
Sweden	No specific legislation therefore no restrictions
Switzerland	The Federal Dept. of Home Affairs is allowed to restrict the use of processing aids but there is currently no positive list. Residues remaining in foodstuffs must be technologically inevitable or reaction products *(Switzerland,2005)*. There is no legislation on processing aids used in beer.
UK	No restrictions except that must be safe in use

More details of enzymes and processing aids allowed in France are shown in Tables 2 and 3 .

Table 2. Enzymes allowed in beer and brewing in France *(France, 2013).*

Enzyme activity	Source
Acetolactate	*B. subtilis* with *B. brevis* gene
α-amylase	*B. licheniformis, B. subtilis,* (non-GM) *A.niger, A oryzae* (non GM) *B. licheniformis* + specified GM types *B. amyloliquefaciens* WR (GM) *Trichoderma reesei* with *A. kawachii* gene
Aminopeptidase	*A. oryzae* (GM)
Amyloglucosidase	*A. niger* with *Talaromyces emersonii* gene *A.niger, A oryzae* (non GM) *Trichoderma longibrachiatum* (GM)
β-Amylase	Wheat
β-Glucanase	*A. niger* (non-GM) *B. amyloliquefaciens, B. subtilis,* (non-GM) *Disporotrichum dimorthosporum* (non-GM) *Talaromyces emersonii* (non-GM)
Cellulase	*Trichoderma longibrachiatum (ex-reesei)* A83, T V
Endo- β-glucanase	*Geosmithia emersonii* BWW 1016.2 (non-GM) *Humicola insolens* (DSM 1800)
Papain	*Carica papaya*
Pentosanase	*Humicola insolens* (DSM 1800)
Protease	*A.niger, A oryzae* (non GM) + *A.niger* GEP44 (GM) *B. licheniformis, B. subtilis,* (non-GM) *B. amyloliquefaciens* *B. subtilis* (EP) with *B. amyloliquefaciens* gene
Pullulanase	*Klebsiella planticola* 15050 *B. acidopullulyticus* *B. subtilis AO* with *B. acidopullulyticus* gene
Xylanase	*A oryzae* with *A. aculeatus* gene

Table 3. Processing aids for brewing in France *(France, 2011, 2013).*

Substance	Use	Conditions
Cellulose	Clarification	Minimum needed (c. 100g/m^2 of filter)
Activated carbon		Minimum needed. 10 – 100g/hl
Carrageenan		Residues </= 10mg/L
Fish collagen		
Silicon dioxide		
Tannins		
PVP/polystyrene	Filtration	50 – 100 g/hl
Perlite		Minimum needed. 5 – 100g/hl
Polyamide 11		Minimum needed. Residues < 0.2mg/litre
PVPP		Residues </= 1mg/ L
Diatomite (KG)		
HCl , $CaCl_2$, $MgCl_2$, ZnCl	pH regulation	
Lactic acid		
H_3PO_4		
H_2SO_4, $CaSO_4$, $MgSO_4$, Zn_2SO_4		
Na_2CO_3		
$Ca(OH)_2$		

2.3 WHO and other international standards

The **Codex Alimentarius Commission** of the WHO and FAO has developed a standard for processing aids *(CAC, 2010a).* This states that:

- Processing aids should be used under the conditions of Good Manufacturing Practice
- The quantity used should be the lowest level required to achieve the desired result
- Residues or derivatives should be reduced to the lowest level reasonably achievable and must not pose a health risk
- Any unavoidable residues must not perform a technological function in the final product
- Substances used as processing aids should be of food grade quality, should comply with any applicable microbiological criteria and should be handled in the same way as food ingredients.

It is the responsibility of the supplier or user to demonstrate the safety of a processing aid for its intended use. This includes assessment of unintended or unavoidable residues.

Codex maintains an Inventory of Processing Aids, last updated in 2009 and presented to the Codex Committee on Food Additives in 2010 *(CAC, 1999: 2010b).* This Committee is in the process of developing a database of processing aids *(CAC, 2012).*

The **Food Chemicals Codex**, which is maintained by the US Pharmacopeial Convention, is also available as an online database, by subscription *(FCC, 2013).* The database is arranged in a series of monographs for a wide range of substances used as food additives and processing aids, each containing details of identity and purity criteria.

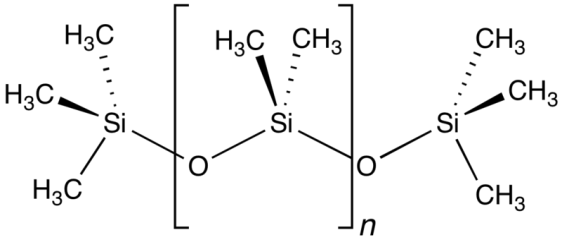
3. Specific processing aids

NOTE: A Report on Residues of Processing Aids in brewing co-products was commissioned by The Brewers of Europe in 2012. The theoretical residues calculated for that report are given below under the appropriate substance and referenced as Brewers of Europe, 2012.

3.1Antifoams

3.1.1 Antifoam (Dimethyl polysiloxane: E900)

- **Chemistry:**



CAS. No. 63148-62-9
8050-81-5
INS No. 900
EU No: E900

The polysiloxanes are high molecular weight polymeric silicones, the most commonly used of which is DMPS. DMPS is a translucent viscous liquid, with molecular weight in the range 6,000 – 38,000. It is described as consisting of fully methylated linear siloxane polymers consisting of units of the formula $(CH_3)_2$ SiO, with trimethylsiloxy end-blocking units with the formula $(CH_3)_3$ SiO *(FAO, 1992).*

- **Use:** Dimethylpolysiloxane (DMPS) is used to prevent excessive foaming during fermentation, and is added to the wort after boiling, prior to fermentation. Manufacturer's recommended dose rate is 500ml product/1000 litres wort, where the product contains 20% silicone (equivalent to 100mg silicone/litre of fermenting wort) *(Basildon Chemicals).*
- **Toxicity:** The most recent evaluation of DMPS by JECFA was in 2008, when the existing ADI of 0 – 1.5mg/kg body weight was withdrawn and a temporary ADI of 0 – 0.8 mg/kg body weight was set *(JECFA, 2008)*. Studies with both low MW (molecular weight) material of 1000 and high MW material of 10,000 indicated that for both substances most of the DMPS was excreted unchanged in the faeces. No toxic effects were observed in short term toxicity tests. In chronic toxicity tests, the No Observed Effect Level (NOEL) for systemic toxicity and carcinogenicity was very high (1000mg/kg body weight/day) but adverse effects on the eyes was observed at lower doses. The temporary ADI was therefore set until the mechanism causing damage to the eyes was explained.
  EFSA have assessed the toxicological risk to humans of silicon both derived naturally from foods, and from food additives/processing aids such as DMPS *(EFSA, 2004).* Although silicon has not been demonstrated to be an essential nutrient for humans, it plays an important role in the structure of connective tissue and in bone calcification. Silicon was not found to be a genetic, reproductive or developmental toxin and EFSA were not able to determine an Upper Tolerable Limit. Furthermore, they estimated that the bioavailability of silicon from additives such as DMPS was low, and did not significantly increase the intake of silicon above that present naturally in food.

- **Behaviour during brewing and residues:** DMPS has low water solubility, and most of the added material is lost with the yeast, on the walls of the fermenters and associated vessels and pipework and on the filters.
  No residue limits have been set by JECFA for residues of DMPS in **beer.** Residue limits of 10mg/litre are set for fruit juices *(CAC, 2010b).* Baker & Boddy *(1977)* reported residues of around 1% of the added silicone in the beer, whilst Sinclair and Hallam *(1971)* detected DMPS at concentrations of 0.89 – 1.15 mg/litre.
  Brewers' grains: No residues of DMPS *(Brewers of Europe, 2012).*
  Brewers' yeast: 210mg DMPS / kg yeast (0.021%) on a dry basis *(Brewers of Europe, 2012).* Sinclair and Hallam *(1971)* reported residues of 21mg DMPS/litre of yeast slurry.
  Feed beer: 1mg DMPS / litre beer *(Brewers of Europe, 2012).*
- **Specific legislation:**
  - **EU:** In the Materials in contact with food legislation, silicones are listed in Annex 1 as materials which *may* be subject to specific legislation in the future.
  - **Germany:** Antifoams are not allowed to be used in beer brewed according to the Reinheitsgebot.
  - **US:** DMPS is allowed for use in the processing of foods, with an upper limit of 10ppm in the food as consumed. Specifications for viscosity and refractive index are also set *(CFR, 2013).*

3.1.2 Hop-based antifoams

- **Chemistry:**
  CAS. No. none
  INS No. none
  EU No: none

  These are patented products produced from the natural lipid and wax fraction of hops remaining after the extraction of alpha-acids with carbon dioxide, together with food grade emulsifying agents (for example, sunflower lecithin) *(Botanix & Marriott, 2008: Barth-Haas, 2012).*
- **Use:** It is recommended that these products should be dosed into cold wort prior to fermentation. Dose rates depend on the brewing recipe and fermentation conditions but are generally in the range 5 – 50g/hl *(Botanix).* In trials they have been shown to improve the efficiency of fermentation and have no adverse effects on beer quality or flavour *(Marriott et al, 2008).*
- **Toxicity:** Hop-based antifoams are prepared from food ingredients and as such would not be expected to be toxic.
- **Behaviour during brewing and residues:** The hop substances present in antifoams are lipophilic, and some will remain with the spent yeast and cold break. Some do persist into the beer, where they associate with other hydrophobic molecules particularly in the beer foam *(Ford et al, 2012).*
- **Specific legislation:**
  - **Germany:** Antifoams may not be used in beers brewed according to the Reinheitsgebot.
  - **US:** Hop-based antifoams are permitted in the US for use in brewing *(TTB, 2014).*

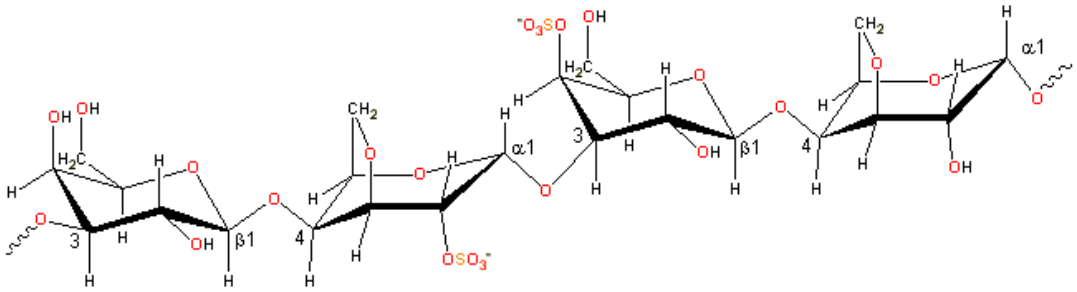
3.2 Enzymes

Full details of the use of enzymes in brewing, together with their behaviour during brewing and toxicity, are given in The Brewers of Europe TIS "Enzymes", 2012.

3.3 Finings/clarifying aids

3.3.1 Carrageenan (E407) and Processed Eucheuma Seaweed (E407a)

- **Chemistry:** **CAS. No:** 9000-07-1
  9062-07-1 (i-carrageenan)
  INS No: 407
  E No: 407
  EINECS: 232-524-2



Carrageenan – representative structure.

Carrageenan is a colloidal water-soluble gum which occurs naturally in several species of red marine algae (*Rhodophyceae* species) and is extracted using aqueous dilute alkali, then precipitated with alcohol or potassium chloride. It consists of highly sulphated polymers of alternating α-D- and β-D-galactose and anhydrogalactose units and is therefore has a strong negative charge. There are three different forms of carrageenan, kappa, iota and lambda, which differ in their sulphate content and charge. Processed Eucheuma seaweed is extracted from *E. cottonii* or *E. spinosum*, using strong alkali to coagulate the carrageenan and cell wall material. In contrast to traditionally refined carrageenan, processed Eucheuma seaweed also contains cellulosic debris from the plant cell walls.

- **Use:** Carrageenan is added to the kettle. Commercial carrageenans (E407) used in brewing are generally mixtures of kappa-carrageenan, which binds efficiently with wort proteins which could form chill haze, and iota carrageenan, which improves the cohesive strength of the flocs *(Priest & Stewart, 2006).* Addition rates can be up to 20 – 50 ppm (mg/litre) *(Brewers Supply Group, Wort clarification)*. Processed Eucheuma seaweed (E407a) consists of kappa and lambda carrageenans in proportions which depend upon the relative amount of each species.
  Carrageenan is also widely used as a food additive in foods such as creams, spreads and purees, with maximum limits of either *quantum satis* or up to 10,000mg/kg *(EU, 2008c).*
- **Toxicity:** Although early reports have suggested that carrageenan could act as a

tumour promoter for colon cancer, more recent studies found that concentrations of up to 5% in the diet (well above estimated human intakes) did not promote colon carcinogenesis. JECFA considered that intakes of both carrageenan and processed Eucheuma seaweed from their use as food additives were not a concern, and allocated a Group ADI of "not specified" *(WHO, 2002).* There have also been concerns that low molecular weight or degraded carrageenan could be harmful. In their review, the SCF recommended that an upper limit of not more than 5% of material below 50kDa should be introduced into the specifications. They rejected the hypothesis of Tobacman *et al* that consumption of water soluble polymers such as carrageenan could be linked to an observed rise in breast cancer in the US and retained the ADI of 0 – 75 mg/kg body weight set in 1978 *(SCF, 2003).* The combined dietary intake of carrageenan and processed Eucheuma seaweed from their use as food additives are in the range 30-50mg/person/day. EFSA has reviewed reports that carrageenan can become contaminated with SEM (semicarbazide, a suspect carcinogen) due to the use of hypochlorite during manufacture *(EFSA, 2005).* They concluded that intake of SEM via this route would not be more than 0.005µg/kg body weight for a person consuming carrageenan at the limit of the ADI (75mg/kg bodyweight). This amount was negligible compared with potential exposure to SEM from the use of azodicarbonamide in packaging. They also noted that SEM was a weak non-genotoxic carcinogen with a threshold of toxicity. A margin of at least 5 orders of magnitude existed between the dose causing tumours in experimental animals and dietary exposure to humans.

Carageenan can contain up to 50mg/kg of formaldehyde, although use is being phased out by some manufacturers. The formaldehyde is added during manufacture to prevent depolymerisation of raw material. EFSA considered that this would not pose a health risk, since a worst case estimation of dietary exposure to foods containing carageenan and alginates as a gelling agents would still be much lower than the WHO TDI (Tolerable Daily Intake) of 150 µg/kg body weight for formaldehyde from drinking water *(EFSA, 2008).*

- **Behaviour during brewing and residues:** Most of the carrageenan is precipitated with the trub during wort boiling. Analysis of beer suggests that less than 1mg/litre remain in the beer *(Buckee et al, 1976).* Assuming that all the carrageenan not remaining in the beer is precipitated during wort boiling, and the trub returned to the mash or mixed with the brewers' grains, brewers' grains could contain 0.98g carrageenan/kg dry grains, or 0.86 g /kg brewers' grains at 12% moisture.
- **Specific legislation:**
  - Carrageenan and processed Eucheuma seaweed are authorised food additives in the EU. Carrageenan is generally allowed at quantum satis level.
  - Purity criteria for carrageenan and processed Eucheuma seaweed are set by EU Regulation 231/2012 *(EU, 2012).*
  - Purity criteria for carrageenan (the definition of which includes furcellaran) are also set by JECFA *(JECFA, 2007).*

3.3.2 Furcellaran

- **Chemistry:** **CAS. No:** 9000-21-9
  INS No: 407
  E No: E407
  EINECS: 232-524-2

  Furcellaran is extracted from the seaweed *Furcellaria jastigiata* and very similar in structure to kappa-carrageenan but contains fewer sulphate esters. The ratio of sulphates to sugars is 1:2 in kappa carrageenan but 1: 3 or 4 in furcellaran. It therefore has a weaker charge.
- **Use:** Furcellaran is used in the same way as carrageenan, to clarify wort by combining with and removing proteins. It has been largely replaced by carrageenan. Dose rates would be similar to those for carrageenan.
  Furcellaran is not an authorised food additive in the EU, but is a listed additive for foods in the US.
- **Toxicity:** Because of the structural similarities between carrageenan and furcellaran, the two materials are often considered together in toxicity evaluations. Furcellaran was last reviewed by JECFA in 1984, when an ADI of "not specified" was assigned for carrageenan and furcellaran *(WHO, 1984).* Carrageenan and furcellaran were last reviewed by the SCF in 1978, when a group ADI of 0-75 mg/kg body weight was set for the two substances *(SCF, 1978).*
- **Behaviour in brewing and residues:** Most of the added furcellaran would be expected to be precipitated during wort boiling and removed with the trub. Residues of furcellaran detected in beer were around 0.5 mg/litre *(Buckee et al, 1976),* suggesting that, at a dose rate of 50mg/litre of wort, over 99% of added furcellaran is lost during brewing. Assuming that this was all in the trub, and that the trub was returned to the mash or mixed with the brewers' grains, then dry brewers grains could contain up to 0.99g furcellaran /kg, equivalent to 0.87 g /kg brewers' grains at 12% moisture *(The Brewers of Europe, 2012).*
- **Specific legislation:** The Codex Alimentarius Food Additives database classes carrageenan and furcellaran together (INS No 407) and one set of specifications are defined *(JECFA, 2007).*

3.3.3 Gelatine

- **Chemistry:** **CAS. No.** 9000-70-8
  Enumber: E441 (but no longer included in list of EU additives: classified as an ingredient).
  EINECS: 232-554-6

  Gelatine is a protein. It is composed of a mixture of different sized polypeptides which are rich in glycine, proline and hydroxyproline amino acids. A typical amino acid sequence would be: **-**Ala-Gly-Pro-Arg-Gly-Glu-4-HyP-Gly-Pro-. It is prepared by the partial hydrolysis of collagen from hides or bones. Gelatine used in brewing is normally from bovine collagen. Such mammalian collagens are less soluble than isinglass, but are stable at up to 40°C *(Hickman et al, 2000).* In recent years, porcine gelatine has become more widely used in fining. The chemical

properties and amino acid composition of porcine and bovine gelatines are very similar. Porcine gelatine has a higher gel strength over the pH range, whilst bovine gelatine has higher foam stability *(Raja Mohd Hafidz et al, 2011).*

- **Use:** Gelatine is used in brewing in the same way as isinglass to clarify beer by removing haze proteins and yeast. The fining properties of gelatine are very similar to those of isinglass in that it is unaffected by pH, chelating agents, detergents and yeast proteins, but it is not widely used in brewing in Europe.Fining efficiency is affected by both molecular weight (MW) and isoelectric point. The MW of mammalian finings can be controlled by the extent of hydrolysis during the production process Gelatine also has a lower iso-electric point than isinglass, which means that it may be better for fining certain products.
  Gelatine, particularly porcine gelatine, is used in wine making to remove tannins. It is also widely used as a gelling agent in foods. In health care, it is used in medical implants and in capsules for medicines.
- **Toxicity:** Gelatine is a mammalian protein widely used in food and is not considered toxic provided that residues from processing are within acceptable limits. Food grade gelatine should be used for brewing (see "Specific legislation"). There have been concerns that gelatine prepared from bovine bones could pose a risk for vCFD in countries where BSE occurs. EFSA concluded that the risk of vCJD from gelatine was very low, even for that produced from the vertebral columns of cattle *(EFSA, 2006).*
- **Behaviour in brewing and residues:** Gelatine is added to beer after fermentation and the main separation of yeast, prior to filtration. Usual addition rates are in the range 2 – 12 g/hl, typically around 5g/hl *(Weissenbach, 2000).* It reacts with beer polyphenols and haze proteins, forming large flocs. These are removed on the filter. There is no published information relating to gelatine residues in beer. Residues of up to 0.33mg/litre were found in wines fined with fish collagen at similar addition rates to those recommended for beer, and these were removed by subsequent treatment with bentonite. No residues of the fish gelatine were detected in commercial wines *(Weber et al, 2007, 2010).*
  If it is assumed that, in the worst case, 99% of added gelatine is removed by the filter and 1% survives into the beer, then residues remaining in beer could be in the range of 20 – 120mg/hl (0.2 – 1.2 mg/litre).
- **Specific legislation:**
  - The European Commission has set specific rules for gelatine production. These cover the countries and establishments where gelatine is produced, record keeping and specifications, microbiological criteria and residues, and also handling of the animal starting materials *(EU, 1999).* These specifications for gelatine were reviewed by the SCF in 2002, when many of the microbiological criteria were relaxed and limits for heavy metals were adjusted. *(SCF, 2002).*
  - Beers and wines fined with fish gelatine are exempt from allergen labelling legislation *(EU, 2011b).*
  - Many non-EU countries also set purity specifications for gelatine.

3.3.4 Isinglass

- **Chemistry:** **CAS. No:** 91053-28-0

  Isinglass used in brewing is a pure form of collagen (greater than 92% collagen on a dry, ash free basis). It is derived from the swim bladders of specific tropical and sub-tropical fish. The isinglass solution used consists mainly of solubilised collagen molecules (mostly as dimers and trimers with molecular weights of 800-1300kDa) together with lesser amounts of gelatine (denatured collagen), low levels of elastin plus low levels (<5% concentration) of other non-collagenous material. It has a high hydroxyproline content which allows the formation of H-bonded bridges through the hydroxyl group and along the peptide chain. This stabilises the triple helix structure which is essential for finings action. Finings capability is unaffected by pH, chelating agents, detergents and the removal of yeast surface proteins. Surface charge and higher molecular weight both increase finings efficiency *(Hickman et al, 2000).* Commercial isinglass products also contain traces of Gad c1 parvalbumin, which is an allergen. Parvalbumin can be present at concentrations of up to 30µg/gm. However, for isinglass produced under the BfBi Code of Practice, these levels are typically 1µg/gm *(BFBi, 2006a)*.
- **Use:** Isinglass is used as a fining agent in beer. In beer it has a net positive charge which reacts with the negative charges on yeast and beer haze proteins, causing the formation of large flocs which may sediment or can be more easily removed on the filter. In cask conditioned beers, the isinglass is dosed into the beer immediately before packaging and remains in the cask, where it forms a sediment.
- **Toxicity:** Isinglass itself is a fish protein (collagen) which has been consumed as a food for centuries. There is no evidence that it is toxic. However, a small proportion of the human population is allergic to fish and these individuals cannot consume fish**.** The allergen has been identified as a protein called parvalbumin, similar forms of which are found in most bony fish. Gad c1parvalbumin is the type first identified in cod *(Gadus callarias).* Parvalbumin is mainly associated with fish muscle protein, thus the concentrations in swim bladders are naturally low. The BFBi Code of Practice *(BFBi, 200b)* restricts the fish types used to those low in parvalbumin and also includes a purification procedure which further reduces parvalbumin concentrations in the purified isinglass. Clinical trials using this purified isinglass did not trigger allergenic reactions in individuals with fish allergy.
- **Behaviour in brewing and residues:** For brewery-conditioned beers, isinglass is added at the end of the primary fermentation. At this point the beer contains large quantities of yeast and suspended protein solids: the contribution from yeast is typically in the range 100 to 400 mg/l (dry solids) equivalent to $1x10^6$ to $4x10^6$ cells/ml, whilst protein particles contribute a further 150 to 300 mg/l (dry solids). The isinglass reacts with the flocculating yeast and protein particles, causing them to sediment rapidly at the base of the storage vessel, so that the majority can be removed prior to filtration. The dosage rate of isinglass is typically 15 mg/litre for brewery-conditioned beers. Isinglass residues are typically in the range of 1 – 3 mg/litre for small-pack and keg beers respectively.

For cask-conditioned beers (common in the UK), the isinglass is dosed either into the beer before it is transferred to the cask or directly into the cask. Finings action takes place generally within the first 3 to 4 hours after filling so that the flocculated solids (yeast plus isinglass plus protein) rapidly settle to the base of the cask, forming a compact sediment. The beer is drawn from the cask to a point above the sediment, so that it remains bright and free of suspended particles. Dosage rates for cask-conditioned beers are typically in the range 35-60 mg/litre. Isinglass residues are typically around 5 mg/litre.

- **Specific legislation:** The EC has exempted the use of isinglass in beer and wine from triggering allergen labelling *(EU, 2011b).*

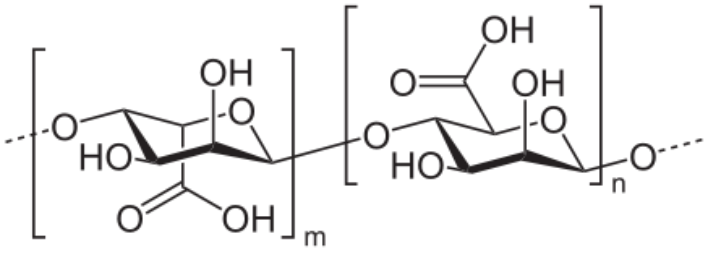
3.3.5 Silicates

CAS.No: 10101-39-0 (salt of silicic acid)
1344-95-2 (salt of orthosilicic acid)
INS No: 552
E No: E552 (calcium silicate)
EINECS: 215-710-8

- **Chemistry:** Calcium silicate (E552) is an inorganic substance which can exist either as the calcium salt of silicic acid (H_2SiO_3) or the calcium salt of orthosilicic acid (H_4SiO_4). The formulas are $CaSiO_3$ and Ca_2SiO_4 respectively.
- **Use:** Calcium silicate and other acidified silicates may be used as auxiliary finings to clarify beer. They carry a net negative charge (the opposite to that of isinglass finings) so will bind to and remove positively charged materials which are unaffected by isinglass. They must not however be added at the same time as isinglass or other positively charged finings or the two materials will neutralise each other out with a net loss of finings action.
- **Toxicity:** See 3.4.4, Silicon dioxide
- **Behaviour during brewing and residues.** Silicates are added to the beer generally about 24 hours prior to the addition of isinglass.
- **Specific legislation:**
  - **Purity:** Calcium silicate used in brewing should conform to the relevant purity criteria set for calcium silicate used as food additives *(EU, 2012).*
  - **US:** Calcium silicate is listed as "Generally Recognised as safe" (GRAS) in the US Code of Federal Regulations *(CFR, 2013).*

3.3.6 Sodium alginate

- **Chemistry:** **CAS No:** 9005-38-3
  INS No: 401
  E No: E401.



An "M" alginate unit

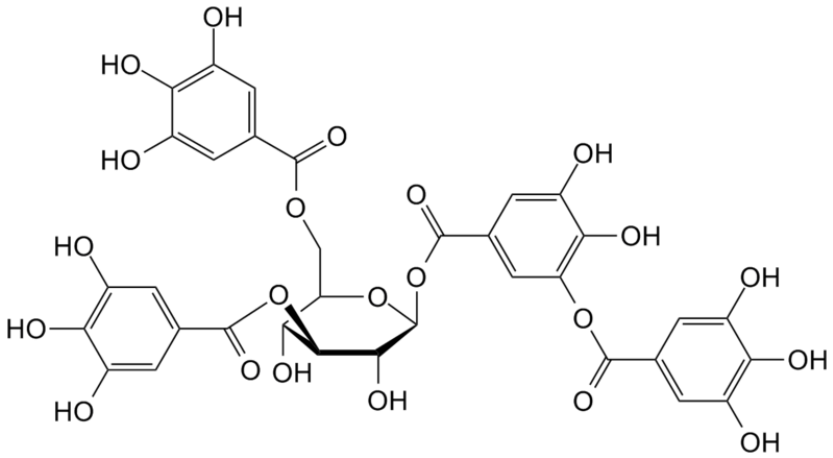
Alginates are salts of alginic acid, found in the cell walls of brown seaweeds. The sodium salt, which is soluble, is usually used in brewing. Alginic acid is a polymer of β-(1,4)-D-mannuronic acid (M) and α-(1,4)-L-guluronic acid (G). Polymers may consist entirely of M units, entirely of G units or a ratio of M/G, depending upon the seaweed species and environmental factors.

- **Use:** Alginates are mainly used with isinglass as auxiliary finings to improve beer clarity. They may also be used in the kettle with or instead of carrageenan, to assist protein precipitation and improve the clarity of the wort.
- **Toxicity:** Alginates have been evaluated by JECFA several times and an ADI of "not specified" was set in 1992 *(FAO, 1997).*
  Alginic acid and its salts can contain up to 50mg/kg of formaldehyde, added during manufacture to prevent depolymerisation and as an antioxidant and bleaching agent. EFSA considered that this would not pose a health risk, since a worst case estimation of dietary exposure to foods containing alginates as a gelling agents would still be much lower than the WHO TDI (Tolerable Daily Intake) of 150µg/kg body weight for formaldehyde from drinking water *(EFSA, 2008).* EFSA considered that formaldehyde was not carcinogenic by the oral route. A limit of 50µg/kg has now been incorporated into the EU purity specifications for alginic acid and alginates *(EU, 2012).*
- **Behaviour in brewing and residues:** Alginates are negatively charged and promote the precipitation of positively charged proteins. Alginates added during wort boiling to aid wort clarification will react with proteins and be precipitated and removed in the trub. Alginates used as auxiliary finings are removed with the yeast and on the filter. Analysis of beers produced with alginates either as copper finings or auxiliary finings did not detect any residues greater than 1mg/litre *(Buckee et al, 1976).*
- **Specific legislation:**
  - **Purity:** Specifications for alginic acid and alginates are given in EU food additives legislation *(EU, 2012).* JECFA has also set specifications: these do not include a limit for formaldehyde *(FAO, 1997).*
  - **US:** Alginic acid is listed as a direct food substance Generally Recognised as Safe (GRAS) *(CFR, 2013b).*

3.3.7 Tannic acid / gallotannins

CAS No. 1401-55-4
INS NO: 181
EINECS: 215-753-2

- **Chemistry:** Commercial tannic acid is a naturally occurring plant polyphenol and is a polymer of gallic acid, although technically it is not itself an acid. Most of the gallotannins used in brewing are hydrolysable tannins and are complex mixtures of polygalloylglucoses or polygalloyl quinic acid derivatives. The number of gallic acid units varies with the plant source, but tannic acid products used in brewing operations are generally medium to high molecular weight (between 975 and 2000) *(Mussche, 1990).*



- **Use:** The phenolic groups in tannic acid react with haze proteins in wort and beer, causing them to precipitate so that they can be removed, thus improving the clarity and colloidal stability of the beer. At higher addition rates, it can also react with and remove some of the polyphenols which also contribute to haze formation *(Siebert & Lynn, 1997).*
- **Toxicity:** Tannic acid was evaluated by JECFA in 1989, when an ADI of "not specified" was assigned. The most recent FAO purity specifications were prepared in 2009 *(FAO, 2009).*
- **Behaviour in brewing and residues:** Tannic acid products may be added to the mash, during wort boiling, during beer maturation or immediately prior to filtration, with different formulations available for addition at each stage. In general, products designed to be added at the later stages (maturation and filtration) are more highly purified to avoid introduction of any impurities. Products designed to be added during mashing or wort boiling claim to have strong reducing power to protect against the formation of aldehydes. Addition rates are in the range 1 – 10g/hl, but vary with the processing stage at which the addition is made *(Ajinomoto, 2007).* It is generally assumed that all the tannic-protein precipitate is removed on the filter and no residues remain in the beer *(Jones et al, 1994; Mussche & De Pauw, 1998).*

- **Specific legislation:**
  - **EU:** As a polymer, tannic acid is technically exempt from the REACH legislation (the Registration, Evaluation and Authorisation of Chemicals regulations which replaced the EINECS system (European Inventory of Existing Chemical Substances). However, the major supplier Ajinimoto has pre-registered its tannic acid.
  - **US:** Tannic acid is listed as GRAS *(CFR, 2013b).*
  - **Codex:** Tannin is listed in the Codex Inventory of Processing Aids *(CAC, 1999).*

3.4 Filtration aids

3.4.1 Activated carbon

CAS No. 7440-44-0
FCM No. 984

- **Chemistry:** Activated carbon is carbon which has been specifically processed by thermal decomposition in a furnace under a controlled atmosphere in order to develop a network of thousands of sub-microscopic pores within its structure. These provide adsorption sites by which contaminants, particularly organic molecules, can be removed from a gas or liquid passed over the activated carbon. The processing can be manipulated in order to produce pores within a specific size range or ranges, so that different carbons can be tailor-made for specific purposes. The starting material, which may be any highly carbonaceous material, such as coal, lignite, charcoal, peat or wood, will also affect the properties of the finished material. For example, activated carbons from coconut shell tend to have very small pores, so are more useful for removing small molecules such as trihalomethanes, whilst coal carbon is more effective at removing larger molecules such as pesticides *(Gough, 1995).*
- **Use:** Activated carbon is used for several different purposes in brewing.
  - It is widely used to treat water for use in mashing and/or cutting of high gravity brews to sales gravity. In this application, the aim is to remove impurities such as pesticides and other toxic contaminants in water, and substances which can contribute to off-flavours in the beer, such as disinfection byproducts including chlorine and other halo compounds.
  - Activated carbon is widely used in conjunction with other materials to treat recovered beer (for example, from overfilled packages, first or last filter runnings etc) to allow it to be returned to be blended back into the main product stream *(Moll & Lenoel, 1997).*
  - It is often used to purify air for use in fermentation, yeast propagation, bottling halls and other areas which are particularly vulnerable to microbiological contamination.
  - Activated carbon may be used to remove colour compounds from beer or beverage alcohol streams in order to obtain a clear product *(Siristova & Melzoch, 2009).*
  - Activated carbon may be combined with kieselguhr and other filter aids and used both as a pre-coat, and in the form of filter pads, sheets and cartridges for beer filtration *(Imerys Filtration & Wang, 2013).*
  - Activated carbons can be used to treat brewery effluents.
  - Outside brewing, activated carbon is allowed for use in mixtures designed for oxygen scavenging in food packaging. Activated charcoal is authorised for use in plastic materials and articles for food contact.
- **Toxicity:** Activated carbon itself is classed as non-toxic and non-carcinogenic. The main risk is inhalation of dust by handlers. Some high density carbons may contain respirable silica. Also, when damp activated carbon can take up oxygen and thus deplete atmospheric concentrations. Care must therefore be taken by workers in low oxygen environments. No ADI has been allocated by JECFA although purity specifications have been set.

Activated carbon has also been evaluated by EFSA for use in plastic materials and articles in contact with food and for use in oxygen scavenger mixtures, most recently in 2014 *(EFSA, 2014).* In each case it is noted that the activated carbon should meet the purity requirements set for vegetable carbon (E153) under the EU food additive legislation. *See also "Specific legislation".*

- **Behaviour during brewing and residues:** Activated carbon is insoluble in water and organic solvents and can be completely removed from the beer stream. However, it may contain impurities which are water soluble, so grades used in brewing should conform to recommended specifications for food use (see specific legislation). Very small particles of carbon may also break off and enter the beer or water stream, thus the correct grade with appropriate resistance to abrasion for the application must be used. Particular care must be taken when using activated carbon to purify cutting (breakdown) liquor, since it has been reported that carbon particles remaining in the beer can act as nucleation sites and cause gushing in the beer *(Biering et al, 2013).*
- **Specific legislation:**
  - **Purity specifications** for activated carbon have been set by JECFA, and revised most recently in 2010 *(FAO, 2010).* These include limits for water, acid and alcohol-soluble materials.
  - **Purity specifications** for vegetable carbon food colouring (E153) are set by the EU *(EU, 2008).*
  - **REACH:** Activated carbons are being registered under REACH legislation by the Activated Carbon Consortium *(ACC, 2013).*

3.4.2 Bentonite

CAS. NO: **1302-78-9**
E No: **E558**
EINECS: **215-108-5**

- **Chemistry:** Bentonite is a clay mineral also known as montmorillonite, composed mainly of aluminium silicate. It also contains traces of crystalline silica. It is insoluble in water and beer.
  Use: bentonite may be added to the wort during boiling or to beer during maturation as a clarifying agent. It removes haze proteins but may also affect foam proteins *(Siebert & Lynn, 1997).*
- **Toxicity:** because of its insolubility, bentonite is not absorbed into the body following ingestion and is not therefore toxic via the oral route. It is used in "natural" remedies and in toothpastes. No ADI has been allocated by JECFA. In the US, bentonite is listed as GRAS (generally recognised as safe*(CFR, 2013b)).* However, as with other silica-containing dusts, inhalation can have adverse effects on health. Precautions should be taken to prevent brewery personnel inhaling dust.
- **Behaviour during brewing:** Since bentonite is insoluble in water it would not be expected to remain in the wort or beer but would be precipitated with the trub if added during wort boiling, or removed on the filters if added during maturation.
- **Residues:** No residues likely in beer. Residues may occur in brewers' grains if bentonite is added to boiling wort and the trub is mixed with brewers' grains for animal feed. Typical dose rates are 40 – 100g/hl. As a worst case, if 100g bentonite were added to 1hl boiling wort and the trub was added

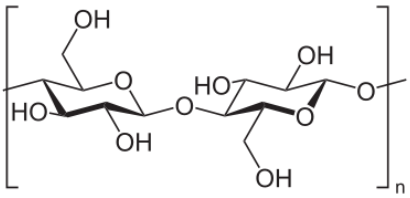
back to the mash or to the brewers' grains, then residues of up to 5g bentonite/kg wet weight grains could be found *(Brewers of Europe, 2012).*

- **Specific legislation:** Workplace limits for amorphous silica are set in most EU countries under EU law. For example, in the UK the limits are: inhalable dust, 6mg/m^3: respirable dust, 2.4 mg/m^3: respirable crystalline silica, 0.1mg/m^3 *(HSE,2012).*

3.4.3 Cellulose

CAS No. 9004-34-6
EU Ref No. 14500 & 43280
FCM substance No. 553 (cellulose);
No. 554 – 562 (modified celluloses)

- **Chemistry:** cellulose is one of the commonest natural polymers, being the major polymer in herbaceous plant cell walls. It is a polysaccharide consisting of D- glucose residues linked together by a β,1-4 linkage This is a straight chain polymer with no side chains or coiling. The hydroxyl units form hydrogen bonds with the oxygen atoms in adjacent chains, forming a rigid structure with a relatively high tensile strength. Cellulose is insoluble in water and is relatively difficult to break down compared with other polysaccharides such as starch.



Cellulose unit

Commercially, cellulose is usually obtained from wood pulp. Three fractions are obtained; alpha-cellulose, which is insoluble, beta-cellulose, which consists of degraded cellulose and is partially soluble and gamma--cellulose, also soluble, which is composed mainly of hemicellulose (hemicellulose is a heteropolymer consisting of cellulose mixed with arabinoxylans and other sugars which increases the solubility).

- **Use:** Cellulose is attracting more interest as a filtration agent, particularly as disposal of kieselguhr becomes more difficult. Cellulose for use in brewing should be mainly alpha cellulose and the proportion of hemicellulose and water soluble substances should be low. Cellulose may be used alone (for example, the Diacel range of filter aids) or in conjunction with other filter agents such as PVPP in order to improve efficiency. *(Fumz & Schaft, 1995).* Cellulose filter pads are also widely used for filtering wine. Hydrolysed and chemically substituted celluloses which may be used as clarifying agents to replace isinglass are also being developed *(Lallemand & Littlewood, 2008).*
- **Toxicity:** Since it is insoluble in water, cellulose used in beer filtration would be completely removed from the beer stream. If traces were to remain in the beer, this would not be a problem since cellulose itself is widely consumed in the diet in vegetables and fruit and is not toxic. However, modified celluloses could contain residues from the manufacturing

process, thus the purity specifications are important. Limits for heavy metals should be included in purity specifications.

- **Behaviour in brewing and residues:** As already noted, cellulose used in beer filtration should be mainly insoluble alpha cellulose, which will be completely removed from the beer. Potential residues remaining in the beer will depend upon the proportion of beta and gamma cellulose. Hemicelluloses are common in food plant cell walls and are not considered toxic.
- **Specific legislation:**
  - Microcrystalline and powdered cellulose are authorised food additives in the EU. Cellulose used as a processing aid in brewing should conform to relevant purity criteria set for cellulose as an additive (for example, water soluble matter, sulphated ash, arsenic and heavy metals) *(EU, 2012).*
  - Cellulose is listed as a starting material and cellulose and several modified celluloses are listed as additives for the manufacture of food contact plastics *(EU, 2011c).* No specific migration limits are set.

3.4.4 Kieselguhr

Full details of the use of kieselguhr in brewing, together with its toxicity and relevant legislation, are given in The Brewers of Europe TIS on Kieselguhr.

3.4.5 Perlite

- **Chemistry: CAS No:** 93763-70-3
  Perlite is a generic name for a naturally occurring, glassy, volcanic rock. Chemically, it is a mixture of silicates, particularly aluminium silicate. Expanded perlite (such as that used in brewing) is produced by heating the raw perlite quickly to above 875°C. The water present in the rock (2 – 6%) vaporises, producing masses of tiny bubbles. The rock expands by up to twenty times its original volume, producing a white, lightweight inert material containing an extensive network of pores. A typical elemental analysis would be: Silicon, 34%: Aluminium, 7%: Potassium, 3 – 4%: Sodium, 3 - 4 %: Iron, 0.6%: Calcium, 0.6%: Magnesium, 0.2%: oxygen, 47 – 48%.
- **Use:** Perlite is used in brewing as a clarification aid for wort and beer. The network of pores in expanded perlite allows it to adsorb particles and remove them from liquids such as beer and other beverages. It is also used in the treatment of drinking water. Perlite is often mixed with kieselguhr, where, although it is slightly less effective as a clarification aid than kieselguhr, it has other advantages such as increasing the stability of the filter cake and reducing the rate of increase in differential pressure during filtration, thus allowing longer filter runs *(Batchvarov et al, 1995).* More recently, blends of different grades of perlite and cellulose fibres have been used together with perlite bodyfeed in order to eliminate the need for kieselguhr entirely *(Müller et al, 2013).* In addition to legal purity specifications, upper limits for leachable metals such as iron and aluminium are also important for brewing use.
- **Toxicity:** As a natural glass, perlite is insoluble and can be removed entirely from the beer stream. The material should conform to purity specifications for food use.
- **Behaviour in brewing and residues:** Since perlite is chemically inert and insoluble, it can

be completely separated from the wort in the hot and cold break, and from the beer stream on the filter. No residues would be expected in the final beer.

- **Specific legislation**
  - **Codex:** perlite is listed in the Codex Alimentarius Inventory of processing aids *(CAC, 1999).*
  - **Purity specifications:** These are set by the Food Chemicals Codex *(FCC, 2013)* and should include upper limits for lead and arsenic. EU food additives legislation also gives purity specifications for several silicates, all with limits of <5mg/kg for lead, <3mg/kg for arsenic and <1 mg/kg for mercury *(EU, 2012).*
  - **US:** Perlite and other silicates are listed as GRAS. The US Select Committee on GRAS substances ruled that their use as filter aids would pose a health hazard *(SCOGS, 2013).*

3.4.6 PVPP

Full details of the use of PVPP in brewing, together with its toxicity and relevant legislation, are given in The Brewers of Europe TIS on PVPP.

3.4.7 Silicon dioxide and silicates

CAS No: 112926-00-8 (silica gel)
7631-86-9 (amorphous silica)
E No: E551 (silicon dioxide, silica gel)
E552 – E559 (silicates)
EINECS No: 231-545-4 (silicon dioxide)

- **Chemistry:** silica gels are polymers of silicic acid, produced by treating sodium silicate with sulphuric acid. The resultant hydrogel (approximately 6% moisture) may be used as is, partially dried to form a modified hydrogel (approximately 30-35% moisture) or completely dried to form a xerogel (<10% moisture).Brewing silicas are porous, amorphous, non-crystalline inert materials.
- **Use:** Brewing silicas are used for clarification and filtration of beer. They act by removing proteins from beer thus increasing its colloidal stability. The pore size can be controlled by the manufacturing conditions to produce gels which can selectively remove certain proteins – for example, haze proteins - without affecting foaming proteins. The selectivity is also enhanced by the tendency to remove proline-rich proteins that are more haze-active. The differing pore sizes can also mean that certain silica gels may be more efficient at removing proteins from brews using different cereals adjuncts. Silica gels may also be combined chemically with PVPP, which binds to polyphenols, to further enhance the stabilization capacity.
- **Toxicity:** The SCF has set a group ADI of “not specified” for silicon dioxide (E551), calcium silicate (E552), magnesium silicate (E553a) and magnesium trisilicate (E553b) *(EFSA, 2009).* Silica gels used in brewing are insoluble and no residues would be expected in beer. If any residues were to be present, the polysilicic acid would not be expected to be very easily absorbed into the body. Silicic acids with a lower degree of polymerisations are more soluble. EFSA have reviewed the safety of silicates and silicic acid (including partly polymerised forms) for use in food supplements *(EFSA, 2009).* (Although silicon is not recognised as an essential nutrient for humans, it is essential for some domestic animals and several recent studies

have demonstrated its importance in the structure of bone and connective tissue in humans and it is increasingly included in food supplements). EFSA considered that although silicon bioavailability is not high, silica gels could be partially hydrated and absorbed by the intestines. Silicon dioxide was found to have no acute and little chronic toxicity. EFSA noted that neither the WHO nor the US Food and Nutrition Board had set an upper limit for dietary silicon. EFSA however adopted the Safe Upper Level of 700mg of silicon /day set by the UK's EVM (Expert Group on Vitamins and Minerals) in 2003. The food supplements were designed to provide up to 700mg/day of silicon, well within the safe upper limit. Even in a worst case, silicon derived from residues of brewing silica gels would be expected to be lower than those provided by such food supplements.

- **Behaviour in brewing and residues:**
  Silica gels are generally added to the beer either during maturation or immediately prior to filtration. They are insoluble and are completely removed from the beer during filtration. No residues would therefore be expected in the beer. It should be noted, however, that beer does naturally contain hydrated silicic acid, formed from the hydration during mashing of silicon naturally present in cereals. Concentrations of silicon in commercial beers are reported to be in the range 6.4 – 56.5mg/litre *(Casey & Bamforth, 2010).*
- **Specific legislation:** silica gels and calcium silicate used in brewing should conform to the relevant purity criteria set for silicon dioxide/ silica gels and calcium silicate used as food additives *(EU, 2012).*

3.5 pH Regulation and Hardness Correction

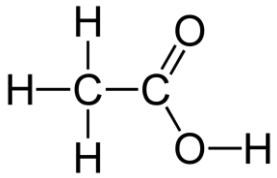
Purity criteria for several chemicals used in brewing as pH regulators or for hardness correction are set by the EU food additives legislation. Relevant details are given in Table 4.

Table 4. Purity criteria for some relevant chemicals in EU legislation *(EU, 2012)*
All values are "Not more than": Units in mg/kg

Chemical	As	Hg	Pb	Cl^-	NO^{3-}	SO^{4-}	Other
Acetic acid	1	1	0.5				
Calcium hydroxide	3		2				Ba – 300 F - 50
Calcium sulphate	3	1	2				F – 30 Se - 30
Citric acid	1	1	0.5				Oxalates - 100
Hydrochloric acid	1	1	1				Fe - 5
Lactic acid	3	1	2	0.2		0.25	Fe - 10
Phosphoric acid	1	1	1	200	5	1,500	Cd – 1 F - 10
Potassium hydroxide	3	1	2				CO_3 – 3.5%
Sodium carbonate	3	1	2				
Sulphuric acid	3	1	2	50	10		Se - 20

3.5.1 Acetic acid

- **Chemistry:**



CAS. No:	64-19-7
Chemical formula:	CH_3COOH
E No.	E260
EINECS:	200-580-7

Acetic acid is a weak organic acid with a pKa (log dissociation constant) of 4.76. It is completely miscible in water and reacts with inorganic bases to form acetates. It is mildly corrosive to metals, except for aluminium, which forms a resistant coating of aluminium oxide. It is also a natural product and is produced by yeast during fermentation.

- **Use:** Acetic acid dissociates to release free hydrogen ions, thus it has an acidifying effect.
  $CH_3COOH \longrightarrow CH_3COO^- + H^+$
  If added at the start of fermentation, acetic acid reacts with coenzyme A to form acetyl-coenzyme A, which is essential for many metabolic reactions in yeast and affects the formation of esters, which have an impact on beer flavour.
  (Note: certain speciality beers achieve a characteristic sour flavour by the use of acetic acid, usually generated by maturing the beer in wooden casks impregnated with acetic acid bacteria, which naturally produce acetic acid. In this case, the acetic acid would NOT be classed as a processing aid).
- **Toxicity:** Acetic acid occurs naturally in a variety of foods, including beer, and is also widely consumed as vinegar. It is also authorised as a food additive in the EU *(EU, 2008c).* It is a normal metabolite in the human body and does not accumulate. The normal daily turnover of acetic acid in the human body has been estimated at around 45g/day and estimations of daily dietary intake are in the range 1 – 2 g/day for adults, which are considered acceptable *(SCOEL, 2012).* This compares with a typical concentration in beer of 100mg/litre *(Gjertsen & Schouboe, 1974).* Although if the concentrated acid is consumed it can have a corrosive effect on the mouth there is no evidence of harmful effects when consumed at low concentrations in beer.
- **Behaviour in brewing and residues:** Acetic acid is produced naturally by yeast during fermentation. The acid added as a processing aid is indistinguishable from that which is naturally produced. In a survey of European beers of different types, the average concentration of acetic acid ranged from 88mg/litre in Pilsners to 1189mg/litre in acid beers *(Klopper et al, 1986).*
- **Specific legislation:**
  - **Purity criteria** are set by the EU food additives legislation *(EU, 2012). See Table 4.*

3.5.2 Calcium hydroxide

- **Chemistry:** **Formula:** $Ca(OH)_2$
  CAS No. 1305-62-0
  E No: 526
  EINECS: 215-137-3

  Calcium hydroxide is a weak mineral alkali. It is only slightly soluble in water. It will react with dissolved carbon dioxide to form insoluble calcium carbonate, which precipitates out of solution and is removed with the brewers' grains or trub.
- **Use:** Calcium hydroxide can be used to raise the pH (residual alkalinity) of the mash or wort, often to counteract the natural acidity of the grist. Calcium additions may also be used to increase the permeability of the mash bed and improve filtration *(Moll, 2004).*
- **Toxicity:** Oral exposure to concentrated calcium hydroxide can cause serious irritation and burns to the gastrointestinal tract and internal organs because of its alkalinity. However, calcium hydroxide added to wort is highly diluted and present as calcium and hydroxyl ions which are indistinguishable from those present naturally, derived from raw materials and water. Calcium is an essential nutrient for humans. The Nutrient Reference Value (NRV) for calcium in the EU is 800mg a day *(EU, 2011b).*
- **Behaviour in brewing and residues:** When calcium hydroxide is added to the mash and wort some of the calcium ions will react with other ions present (carbonate, bicarbonate, oxalate, etc) to form insoluble calcium salts which are lost with the brewers' grains and trub. The remaining calcium ions remain in solution and persist into the beer, where they have a positive effect on the flavour. The natural concentration of calcium in beer is mainly affected by the amount present in brewing water and can range from 25mg/litre in beers brewed with soft water to 120mg/litre in beers brewed with naturally hard water.
- **Specific legislation:**
  - Calcium hydroxide is an authorised **food additive** in the EU (although not for beer) and can be added to many foods up to the concentration required *(quantum satis) (EU, 2008c).*
  - **Purity criteria** are set under the EU food additives legislation *(EU, 2012). See Table 4.*
  - The **Nutrient Reference Value** for calcium is set in the Food Information for Consumers Regulations *(EU, 2011b).*

3.5.3 Calcium sulphate

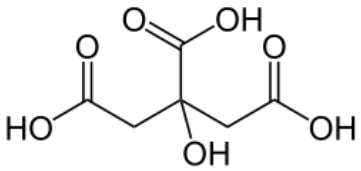
- **Chemistry:**
  Formula: $CaSO_4$ (anhydride): $CaSO_4.2H_2O$ (dihydrate).
  CAS No: 7778-18-9 (anhydride): 10101-41-4 (dihydrate)
  E No: E516
  EINECS: 231-900-3

  Calcium sulphate is an inorganic salt which is relatively insoluble in water. It dissolves at parts per million concentrations at 35°C, and solubility progressively declines at higher temperatures.
- **Use:** Salts such as calcium sulphate (or calcium chloride) can be used instead of acids to adjust pH as well as raising the calcium content. For a given brewing liquor composition, calcium salts are more effective at reducing mash pH than wort pH *(Funnell, 2002).* The weight of salt

needed to achieve the desired pH change in wort is generally significantly higher than the weight of acid required *(Moll, 2004)*. However, the use of calcium salts rather than pure acid has other advantages in that the calcium promotes the precipitation of phosphate and also of oxalate (which can cause haze problems in beer) *(Narziss et al, 1986).* This can be especially useful when brewing with wheat malts, which tend to be higher in oxalate than barley malts.

- **Toxicity:** The safety of a number of cations and anions present in food has been assessed by the SCF *(SCF, 1991).* A group ADI of "Not specified" was assigned for the cations ammonium, calcium, sodium, potassium and magnesium. The Committee further noted that the anions chloride, sulphate and carbonate were natural constituents of man, animals and plants, and were the major electrolytes present in all biological materials. They therefore assigned a group ADI of "Not specified" for these three anions.
- **Behaviour in brewing and residues:** Because of its low solubility, much of the calcium sulphate added at the mash stage will be lost with the brewers' grains and trub. Any which does dissolve will add to the calcium and sulphate ions present in the wort and is indistinguishable to that derived from other sources.
- **Specific legislation:**
  - Calcium sulphate is an authorised **food additive** in the EU although it is not allowed for use as an additive in beer *(EU, 2008c.*
  - **Purity specifications** are set by Regulation 231/2012 *(EU, 2012). See Table 6.*
  - The **Nutrient Reference Value** for calcium is set in the Food Information for Consumers Regulations *(EU, 2011b).*

3.5.4 Citric acid



Formula: $C_6H_8O_7$
CAS No: 77-92-9
E No: E330
EINECS: 261-069-1

- **Chemistry:** Citric acid is a weak organic acid. It is a natural product, found in fruit especially citrus fruit and is a natural constituent of beer. It is also an essential metabolite in all aerobic animals, including humans. It is highly soluble in water.
- **Uses:** Citric acid is an authorised additive in the EU, being used as a preservative, acidifier and a flavouring. In brewing it can be used as a pH regulator.
- **Toxicity:** As an essential metabolite in the human body and a widespread natural component in foods, citric acid is regarded as having low acute and chronic toxicity. It shows no evidence of mutagenicity, carcinogenicity or reproductive toxicity *(OECD, 2001).*
- **Behaviour in brewing and residues:** Citric acid is readily soluble and ionises in solution to form its salt citrate. Some citrate may be precipitated and lost from the brew as calcium citrate, which is insoluble in water.
- **Specific legislation: Purity criteria** are set by the EU food additives

legislation *(EU, 2012). See Table 4.*

3.5.5 Hydrochloric acid

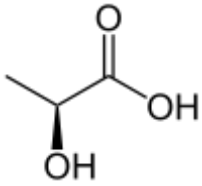
- **Chemistry:** **Formula:** HCl
  CAS No: 7674-01-0
  E No: E507
  EINECS: 231-595-7

  Hydrochloric acid is a strong mineral acid. In its concentrated form (about 33% HCl in water), it is highly corrosive and pungent. It dissociates completely in water to give a chloride and a hydrogen ion and is therefore an efficient acidifying agent.

  $HCl \longrightarrow H^+ + Cl^-$

  Because (a) it is relatively easy to handle; (b) the chloride ion has a low toxicity and (c) it dissociates completely in water, hydrochloric acid is widely used as an acidifying agent in food production.
- **Use:** In brewing hydrochloric acid can be used to acidify the mash and/or the wort. Chloride ions have a positive effect on beer flavour. Hydrochloric acid is also a natural product and is produced in the human stomach.
- **Toxicity:** In its concentrated form, hydrochloric acid, like other strong acids, is highly corrosive to living tissues. Oral exposure causes irritation and burns to the upper gastrointestinal tract and inhalation exposure causes inflammation of the eyes, nose and respiratory tract. However, when added to the mash or wort, hydrochloric acid dissociates completely to form non-toxic chloride and hydrogen ions.
- **Behaviour in brewing and residues:** Hydrochloric acid is completely dissociated into its constituent ions in wort and beer and these are indistinguishable from those derived from raw materials, especially malt. Since most chlorides are soluble, much of the chloride added will persist into the beer unless taken up by the yeast. The chloride content of beer is usually in the range 100 – 500 mg/litre, typically about 300 mg/litre.
- **Specific legislation:**
  - Hydrochloric acid is an authorised **food additive** (E507) in the EU, although it is not allowed as an additive in beer *(EU, 2008c)*.
  - **Purity criteria** are set by the EU food additive legislation *(EU, 2012). See Table 4.*

3.5.6 Lactic acid



Chemical formula: $CH_3CH_2OHCOOH$
CAS. No: 50-21-5
E No: E270
EINECS: 200-018-0

- **Chemistry**
  Lactic acid is an organic acid which occurs naturally in the human body and participates in numerous metabolic reactions. It is very soluble and in aqueous solutions is almost completely ionised to form hydrogen and lactate ions. Thus the terms lactic acid and lactate are

often used interchangeably.

$$CH_3CH(OH)COOH \longrightarrow H^+ + CH_3CH(OH)COO^-$$

In the body lactate is produced from pyruvate as a part of energy metabolism. As part of the glycolysis cycle, during which energy is generated from glucose, the oxidised form of energy-carrying molecule nicotinamide adenine dinucleotide (NAD^+) must be regenerated from the reduced form (NADH). When oxygen is limiting (as during periods of vigorous muscle activity), this regeneration is brought about by the enzyme lactate dehydrogenase, which converts pyruvate and reduced NADH to lactate and NAD^+.

$$\text{pyruvate} + NADH + H^+ \xrightarrow{\textit{Lactate dehydrogenase}} \text{lactate} + NAD^+$$

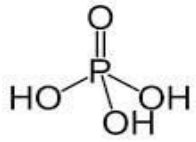
- **Use:** Lactic acid is used to lower the pH (acidify) mash or wort. This may be brought about either by adding the acid itself, or, in countries where this is forbidden, such as Germany, by the use of a lactic acid bacterial culture, usually *Lactobacillus delbruckii (Grutzmacher, 1990: Englmann & Reichert, 1991). L. delbruckii* is a Gram posiitve non-sporulating bacterium which converts lactose and other sugars to lactic acid and carbon dioxide.
- **Toxicity:** As described above, lactic acid is a normal metabolite in the human body, being produced in the muscles, liver and blood cells. Normal lactate production (at a resting state) is around 0.8mmol/kg body weight/hour (72 mg/kg body weight/hour). The normal concentration of lactate in the blood of a healthy adult, which is a result of the balance between lactate formation and lactate removal, is in the range 0.3 – 1.3 mmol/litre (27 – 117mg/litre) *(Phypers & Pierce, 2006).* Most of the lactate in the body is readily removed by the liver, where it is used in the synthesis of glucose and may also be oxidised to form carbon dioxide and water. The rest of the lactate is removed by mitochondria-rich tissues such as the muscles, where it is oxidised to pyruvate *(Phypers & Pierce, 2006).*
- **Behaviour in brewing and residues:** Lactic acid and its salts are very soluble in water so will remain with the wort and beer stream rather than being precipitated with the trub or spent grains. During fermentation, some lactate is taken up by the yeast. *Saccharomyces cerevisiae* can take up lactic acid and convert it to pyruvate and thence to ethanol, although the rate of take up if affected by sugar concentrations and pH.
  In a survey of European beers, average concentrations of lactic acid ranged from 101 mg/litre (range 10 – 259 mg/litre) for Pilsners to 455 mg/litre (range, 62-1362 mg/litre) for acid beers *(Klopper et al, 1986).* It is apparent that, even for acid beers with the highest content of lactic acid, the concentration is well within metabolic concentrations for healthy adults.
- **Specific legislation:**
  - Lactic acid is an authorised **food additive** in the EU and is allowed as an additive in beer at *quantum satis* level *(EU, 2008c).* However, when used for mash and wort acidification, it would be classified as a processing aid rather than an additive. Later additions with the aim of achieving a specific

beer character and flavour would be described as additive use.

- **Purity specifications** in the EU are set down by Regulation 231/2012 *(EU, 2012). See Table 4.*
- ***Lactobacillus delbruckii*** is a Gram +ve non-sporulating bacterium which has QPS (Qualified Presumption of Safety) status in the EU *(EFSA, 2013).*

3.5.7 Phosphoric acid

- **Chemistry:**



Chemical formula: H_3PO_4
CAS No: 7664-38-2
E No: E338
EINECS: 231-633-2

Phosphoric acid is a weak inorganic acid with three ionisable hydrogen ions. It therefore has more of a buffering effect than monoprotic or stronger acids and is easier to handle.

$$H_3PO_4 \longrightarrow H^+ + H_2PO_4^-$$
$$H_2PO_4^- \longrightarrow H^+ + HPO_4^{2-}$$
$$HPO_4^{2-} \longrightarrow H^+ + PO_4^{3-}$$

- **Use:** Phosphoric acid can be used to acidify mash or wort. It may also be used to lower the pH of yeast, thus reducing the risk of bacterial infection *(see Section 3.7.2, Yeast washing agents).*
- **Toxicity:** Like other acids, concentrated phosphoric acid has a corrosive effect on tissues and can cause damage to the gastrointestinal tract if swallowed. Likewise, it can cause damage to the nose and respiratory tract if vapours are inhaled. In dilute solution, however, phosphoric acid and phosphates have low toxicity. Phosphorus is an essential nutrient for humans, being required for calcium metabolism and healthy bone. Phosphate is a normal metabolite in the human body. It is also present naturally in the diet. Excessive intake of phosphates can disrupt electrolyte balance in the tissues and can damage internal organs. The safety of phosphoric acid and phosphates used as food additives was assessed by the Scientific Committee for Food (SCF) in 1991, when the group MTDI of 70 mg/kg body weight, from all sources, expressed as phosphorus, first set by JECFA was adopted *(SCF, 1991).* The Committee noted that phosphates were not mutagenic or teratogenic in test systems and the main health concern was an imbalance of calcium, magnesium and phosphate in the diet. Phosphate added to food as processing aids or additives should be considered together with the natural phosphate content of foods. Although the use of phosphoric acid as a pH regulator does add to the phosphate content of wort and beer, the difference is small compared with the natural content of phosphate in beer, derived mainly from the raw materials.
- **Behaviour in brewing and residues:** Beer typically contains between 90 and 400 mg/litre of phosphorus, largely as phosphates derived from the brewing raw materials. The concentration of phosphorus in malt has been reported to lie in the range 1600 – 2300 mg/kg *(Narziss et al, 1986),* although much of this remains with the brewers' grains. Hops are also a rich source of phosphorus. Some of

the phosphate present in wort is taken up by the yeast as a nutrient.

- **Specific legislation:**
  - Phosphoric acid and several phosphates are authorised **food additives** in the EU, although they are not allowed as additives in beer *(EU, 2008c).*
  - **Purity specifications** are set by Regulation 231/2012 *(EU, 2012).*

3.5.8 Potassium hydroxide

- **Chemistry:** **Chemical Formula:** KOH
  CAS No: 1310-58-3
  E No: E 525
  EINECS: 215-181-3

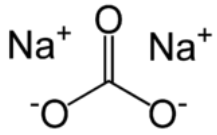
Potassium hydroxide is a strong alkali. It is almost completely dissociated in aqueous solution to give potassium and hydroxide ions.

$$KOH \longrightarrow K^+ + OH^-$$

- **Use:** Like calcium hydroxide, potassium hydroxide can be used to adjust the pH of the wort by making it more alkaline.
- **Toxicity:** Since it is a strong alkali, concentrated potassium hydroxide liquid is highly corrosive and will damage the gastrointestinal tract if swallowed. However, when used as a processing aid in brewing, it is highly diluted and is present in the wort and beer as potassium and hydroxyl ions which are indistinguishable from those already present, derived from the water (hydroxyl) and malt (potassium). Potassium is the major cation present in plant electrolyte systems, with a typical concentration in malt of 3500mg/kg. Potassium is also an essential nutrient for humans. The nutrient reference value (NRV) for potassium in EU legislation is 2000mg for adults *(EU, 2011b).*
- **Behaviour in brewing and residues:** In water potassium hydroxide is completely dissociated into potassium and hydroxyl ions which are indistinguishable from those already present in the wort, derived from the water and the raw materials.
- **Specific legislation:**
  - Potassium hydroxide is an authorised **food additive** in the EU, although it is not allowed as an additive in beer *(EU, 2008c).*
  - **Purity specifications** are set by Regulation 231/2012 *(EU, 2012). See Table 4.*
  - The **Nutrient Reference Value** for potassium is set in the Food Information for Consumers Regulations *(EU, 2011b).*

3.5.9 Sodium carbonate

- **Chemistry:**



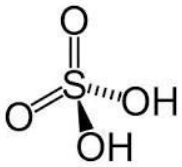
Chemical formula: Na_2CO_3
CAS. No: 497-19-8 (anhydride)
E No: E500(i)
EINECS: 207-838-8
FCM No: 1008

Sodium carbonate is an alkaline salt, being the salt of a strong alkali (sodium hydroxide) and a weak acid (carbonic acid). It is very soluble in water to give a strongly alkaline solution.

- **Use:** Sodium carbonate can be used as an acidity regulator, to raise the pH of the mash or wort. This can be useful in counteracting the acidity of the malt grist, especially where there is a high concentration of dark malts, which are more acidic than pale malts. Sodium carbonate is also permitted for use in active food contact materials, for example in oxygen absorber / carbon dioxide-releasing sachets) *(EFSA, 2014).*
- **Toxicity:** Like all acids and alkalis and their salts, sodium carbonate is corrosive if consumed in its concentrated form and can damage the gastrointestinal and respiratory tracts. In a dilute form, it is not considered to be toxic. The use of sodium carbonate as a food additive has been assessed by the EU's SCF *(SCF, 1991).* The evaluation of ionisable salts such as sodium carbonate was based on separate assessments of the anion and cation. A Group ADI of "not specified" was set for the cations ammonium, calcium, magnesium, potassium and sodium. The anions chloride, carbonate and sulphate are natural constituents of man, animals and plants and, together with certain cations, form the major electrolyte systems in all biological systems. They are therefore found naturally in animal- and plant-based foods, and the human body has well developed systems for controlling their concentration in tissues. The SCF considered that no health problems were likely to arise from presence and consumption in foods as additives and set a Group ADI of "not specified". EFSA are currently re-evaluating the safety of currently authorised food additives and have issued a call for relevant data, with a deadline of January 2013 *(EFSA, 2012).*
- **Behaviour in brewing and residues:** Sodium carbonate dissolves readily in water and is fully ionised to form free sodium ions and carbonate ions, which are indistinguishable from those derived from the raw materials or present in the brewing liquor. Some carbonate may be precipitated with calcium or magnesium to form less soluble salts such as calcium carbonate, which are lost with the brewers' grains and trub. Some of the sodium ions may be taken up by the yeast: the remaining sodium ions will persist into the beer. The natural concentration of sodium in beer is very variable, ranging from 10 – 130mg/litre, with an average around 80 mg/litre.
- **Specific legislation:**
  - Sodium carbonate is permitted as a food additive in many foods (although not beer) in the EU, with no maximum concentration specified other than *quantum satis (EU, 2008c).*
  - Purity criteria are set for sodium carbonate used as a food additive in the EU *(EU, 2012).* Sodium carbonate used as a processing aid in brewing should conform to these purity criteria. See Table 4.
  - Sodium carbonate has GRAS status in the US *(CFR, 2013b).*

3.5.10 Sulphuric acid

- **Chemistry:**



Chemical formula:	H_2SO_4
CAS. No:	7664-93-9
E No:	E513
EINECS:	231-639-5

Sulphuric acid is a very strong, corrosive mineral acid which is fully ionised in water to give two hydrogen ions (plus a sulphate ion). The concentrated acid is very hygroscopic and can explode if water is added: it also causes serious burns if it contacts human tissues and is therefore difficult and dangerous to handle. Concentrated acid should always be diluted by adding acid to water rather than water to acid.

- **Use:** Sulphuric acid can be used to lower the pH (acidify) brewing water, mash or wort. Because it is such a strong acid, it is highly efficient at lowering the pH but, as noted above, it is difficult and dangerous to handle in the concentrated form.
- **Toxicity:** Concentrated sulphuric acid is extremely corrosive and causes serious burns to the respiratory and gastrointestinal tracts as well as to skin. However, when extensively diluted by addition to the brewing stream, it is not corrosive. The safety of anions in food additives has been assessed by the EU's SCF *(SCF, 1991).* The anions chloride, carbonate and sulphate are natural constituents of man, animals and plants and, together with certain cations, form the major electrolyte systems in all biological systems. They are therefore found naturally in animal- and plant-based foods, and the human body has well developed systems for controlling their concentration in tissues. The SCF considered that no health problems were likely to arise from their presence and consumption in foods as additives and set a Group ADI of "not specified".
- **Behaviour in brewing and residues:** Sulphuric acid is fully ionised in water to form hydrogen and sulphate ions which are indistinguishable from those derived from the raw materials or present in the brewing liquor. Sulphate concentrations in beer are typically in the 100 – 700 mg/litre range.
- **Specific legislation:**
  - Sulphuric acid is permitted as a food additive in many foods (although not beer) in the EU, with no maximum concentration specified other than quantum satis *(EU, 2008c).*
  - Purity criteria are set for sulphuric acid used as a food additive in the EU *(EU, 2012).* Sulphuric acid used as a processing aid in brewing should conform to these purity criteria. See Table 4.
  - Sulphuric acid has GRAS status in the US (184.1095) *(CFR, 2013b).* Purity criteria should conform to those set by the Food Chemicals Codex. Use of sulphuric acid in alcoholic beverages should follow the principles of Good Manufacturing Practice, which currently result in a concentration not exceeding 0.014% in the final beverage.

3.6 Yeast

- **Chemistry:** Yeast is a single-celled micro-organism which has the ability to convert pyruvate from glycolysis into ethanol, regenerating oxidised NAD $^{+}$ in the process. It has been used by humans for millennia to produce alcoholic beverages.

$$\text{Pyruvate} + H^+ \xrightarrow{\textit{Pyruvate decarboxylase}} \text{acetaldehyde} + CO_2$$

$$\text{Acetaldehyde} + \text{NADH} + H^+ \xrightarrow{\textit{Alcohol dehydrogenase}} \text{ethanol} + NAD^+$$

Most brewing yeasts are classified as *Saccharomyces cerevisiae* or *S. pasteorianus*. Other yeasts such as the *Brettanomyces (Dekkera)* are used to produce certain beers. There are many different strains of *S.cerevisiae* and *S.pasteorianus* which vary slightly in their characteristics, such as in production of flavour compounds and flocculation habit.

- **Use:** Since yeast is essential for the production, not only of the alcohol and carbon dioxide in beer, but also for much of the product's characteristic flavour, yeast has often been considered as an essential ingredient in beer. However, since the yeast is completely removed from most beers, under EU legislation it is described as a "biological agent intentionally added to food and feed" rather than as an ingredient.
- **Toxicity:** Three species of *Saccharomyces – S. bayanus, S. cerevisiae and S. pasteorianus –* are listed as QPS *(EFSA, 2013).* This means that use of that micro-organism in food or feed has been assessed to ascertain that it does not pose a risk to consumers when used in food or animal feed. The list is re-evaluated by EFSA's BIOHAZARD Panel every year in the light of any emerging information which could affect the status of the assessment.
  There have been a very few reports in the medical literature of cases of invasive infections due *S. cerevisiae (Aucott et al, 1990).* These cases are very rare compared with the very wide, world wide use of *S. cerevisiae* and are usually in severely immuno-compromised individuals. It is however likely that *S. cerevisiae,* or at least certain strains or sub-strains, is at least potentially capable of invading human tissues. It is evident that such incidents are extremely rare to the point of being practically non-existent in the general population. However, invasive fungal infections are becoming increasingly important in chemotherapy, and as techniques such as organ transplants, stem cell therapy become more widely used. Most such infections reported are due to *Candida, Aspergillus (ONSEdge, 2010)* and *Cryptococcus* infections are also important *(Shoham & Marr, 2012).* Less than 1% of infections in oncology wards are due to *S. cerevisiae.* The potential pathogenicity of *S. cerevisiae* has been reviewed by Murphy and Kavanagh, from the National University of Ireland *(Murphy & Kavanagh, 1999).* These authors suggest that organisms isolated from infected patients (virulent isolates) exhibit different characteristics to normal laboratory and industrial strains which allow the organisms to proliferate in feverish patients, to attack red blood cells and to penetrate tissues. These include
    - Ability to survive and grow at 42°C *(McCusker et al, 1994b)*. Optimum growth temperatures for brewing yeasts are normally 31 - 33°C for lager yeasts, but can be up to 39º for ale yeasts.
    - Production and secretion of proteinases (reference given is only for *Candida* species) – *(Kaminishi et al, 1995).* It is generally considered that healthy brewing yeasts do not produce proteinases, but they may do so under stress conditions.
    - Pseudohyphal growth under certain conditions (*McCusker et al, 1994a: Clemons et al, 1994*)

  In their 2013 update, EFSA considered recent reports of opportunistic infections by *S. cerevisiae* and concluded that they did not affect its status as a QPS organism.

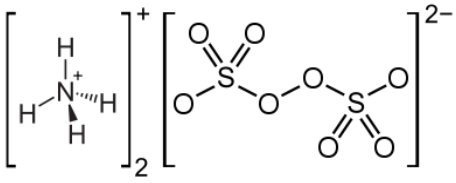
- **Behaviour in brewing and residues:** Yeast is normally either metered into the cooled wort stream while the fermenter is being filled or added directly to the fermenting vessel. In general, each brewery has its own strain of yeast, which may differ slightly from similar strains, giving the beer a unique character. Such breweries will always propagate production yeast from their own culture. Other breweries may buy in a standard yeast strain. Where a brewery-specific yeast is used, the yeast collected from one brew is often repitched into subsequent brews, usually for a set number of cycles before it is re-propagated. In such breweries, the yeast may be "washed" by the addition of yeast cleansing agents in order to reduce bacterial contamination (See Section 3.7). Yeast propagation requires the highest standards of cleanliness and hygiene in order to avoid microbiological contamination. Traditionally, at the end of fermentation the yeast flocculated and collected either on the surface (top-fermenting yeasts) or at the bottom of the vessel (bottom fermenting yeasts). In modern practice, particularly with cylindrico-conical fermenters, at the end of the primary fermentation most yeast strains fall to the bottom of the fermenter and can be readily drawn off. Some yeast may be retained in contact with the beer, or fresh yeast added, during maturation. For most mainstream beers, all yeast is removed during filtration leaving a clear bright liquid. For some speciality beers, all the yeast is not removed and remains with the beer, allowing a second fermentation in the package. Where yeast is not removed from the beer, it is regarded as an ingredient and must be listed in any ingredients list.
- **Specific legislation:**
  - Biological agents intentionally added to food, such as yeast, must be assessed for safety. In the EU, brewing yeasts are listed in the QPS list *(EFSA, 2013) See also Toxicity section.*

3.7 Yeast cleansing agents

Cleansing agents are often used when yeast is to be repitched, in order to prevent a build-up of microbiological contaminants, particularly spoilage bacteria and nitrate-reducing bacteria which can favour the formation of N-nitroso compounds. Acidic compounds are most commonly used, since the yeast is resistant to acid provided that it is kept cold and the pH does not go too low *(Simpson & Hammond, 1989).* However, the viability of the yeast can be affected if washing conditions are not carefully controlled.

3.7.1 Ammonium persulphate

- **Chemistry**



Formula: $(NH_4)_2 S_2O_8$
CAS. No. 7727-54-0
EINECS: 231-786-5

Ammonium persulphate is an inorganic acidic salt. It is highly soluble in water and is a strong oxidising agent.

- **Use:** Acidified solutions (pH around 2.5- 2.8) of dilute ammonium persulphate

(0.75%) are often used for acid washing and have been found to be more efficient at removing *Obesumbacteria proteus* than phosphoric acid *(Simpson, 1987).*
Ammonium persulphate is also used in the laboratory as a cleaning agent, on account of its oxidising properties.

- **Toxicity:** Ammonium persulphate is an irritant and repeated doses can have adverse effects on the gastrointestinal and respiratory tracts. It is negative in tests for mutagenicity and developmental toxicity. The ammonium ion is widespread in biological systems and is non-toxic. Toxicity is therefore mainly influenced by the persulphate anion. This is expected to decay rapidly in solution to form hydrogen peroxide and sulphate ions. Hydrogen peroxide itself is rapidly converted to water and oxygen by catalase and peroxidase enzymes, which are widespread in biological systems *(OECD, 2005)*.
- **Behaviour in brewing and residues:** Some ammonium persulphate used for yeast washing will be rinsed away before the yeast is reused. Any remaining would be expected to be rapidly broken down by yeast enzymes during fermentation and is therefore unlikely to survive into the beer.

3.7.2 Lysozyme

- **Chemistry:**

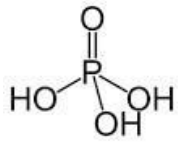
CAS No:	9001-63-2
E No:	E1105
Enzyme Number:	3.2.1.17

Lysozyme is an enzyme which hydrolyses (1→4)-β-linkages between *N*-acetylmuramic acid and *N*-acetyl-D-glucosamine residues in peptidoglycans. It occurs naturally in egg white.

- **Use:** Since such peptidoglycans are common in the cell walls of Gram positive bacteria, lysozyme can therefore be used to inhibit the activity of such bacteria by damaging their cell walls. Lysozyme is an authorised additive in the EU (E No.1105).
- **Toxicity:** The toxicity of Lysozyme was assessed by JECFA in 1993, when it was accepted as a Class 1 enzyme and considered acceptable for use in food processing according to Good Manufacturing Practice *(WHO, 1993).* Since it is extracted from eggs it has antigenic properties and can trigger immune reactions in individuals allergic to eggs. EFSA considered that wines treated with lysozyme could trigger reactions in susceptible individuals.
- **Behaviour in brewing and residues:** Lysozyme can be used as a processing aid to kill Gram positive bacteria in brewing yeast. It has no adverse effects on brewing yeast *(Van Landschoot, 2009).* In most beers any remaining enzyme activity is destroyed by pasteurisation or sterile filtration.
  Lysozyme is also allowed as an additive for use up to *quantum satis* in beers that will are not pasteurised or sterile filtered.
- **Specific legislation:** Beers treated with lysozyme must be appropriately labelled. Purity criteria are set by EU Regulation 231/2012 *(EU, 2012).*

3.7.3 Phosphoric acid

- **Chemistry:**



Chemical formula:	H_3PO_4
CAS No:	7664-38-2
E No:	E338
EINECS:	231-633-2

Phosphoric acid is a weak inorganic acid with three ionisable hydrogen ions. It therefore has more of a buffering effect than monprotic or stronger acids and is easier to handle.

$$H_3PO_4 \longrightarrow H^+ + H_2PO_4^-$$
$$H_2PO_4^- \longrightarrow H^+ + HPO_4^{2-}$$
$$HPO_4^{2-} \longrightarrow H^+ + PO_4^{3-}$$

- **Use:** Dilute food grade phosphoric acid can also be used for acid washing of yeast. The pH is around 2.1. It is reported to have a synergistic effect with hop resins *(Simpson, 1987).*
- **Toxicity:** Like other acids, concentrated phosphoric acid has a corrosive effect on tissues and can cause damage to the gastrointestinal tract if swallowed. Likewise, it can cause damage to the nose and respiratory tract if vapours are inhaled. In dilute solution, however, phosphoric acid and phosphates have low toxicity. Phosphorus is an essential nutrient for humans, being required for calcium metabolism and healthy bone. Phosphate is a normal metabolite in the human body. It is also present naturally in the diet. Excessive intake of phosphates can disrupt electrolyte balance in the tissues and can damage internal organs. The safety of phosphoric acid and phosphates used as food additives was assessed by the Scientific Committee for Food (SCF) in 1991, when the group MTDI of 70 mg/kg body weight, from all sources, expressed as phosphorus, first set by JECFA was adopted *(SCF, 1991).* The Committee noted that phosphates were not mutagenic or teratogenic in test systems and the main health concern was an imbalance of calcium, magnesium and phosphate in the diet. Phosphate added to food as processing aids or additives should be considered together with the natural phosphate content of foods.
- **Behaviour in brewing and residues:** Some of the phosphoric acid used in yeast washing will be rinsed away before the yeast is repitched. Any remaining phosphate is undistinguishable from that already present in the wort, derived from the raw materials. The use of phosphoric acid in yeast washing is unlikely to make a significant difference to the phosphate content of the beer.
- **Specific legislation:**
  - Phosphoric acid and several phosphates are authorised **food additives** in the EU, although they are not allowed as additives in beer *(EU, 2008c).*
  - **Purity specifications** for food additives are set by Regulation 231/2012 *(EU, 2012)* and phosphoric acid used in yeast washing should conform to these specifications.

3.7.4 Sodium hydroxide

- **Chemistry:** Sodium hydroxide is a strong inorganic alkali which is completely dissociated in solution to give sodium and hydroxide ions. In concentrated form it is highly corrosive to living tissues.
  Chemical formula: NaOH
  CAS. No. 1310-73-2
  E No: E524
  EINECS: 215-185-5

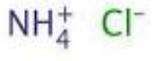
- **Use:** Sodium hydroxide can be used to neutralise the acid used in yeast washing, since prolonged exposure to acid can adversely affect yeast viability.
- **Toxicity:** Since it is a strong alkali, concentrated sodium hydroxide liquid is highly corrosive and will damage the gastrointestinal tract if swallowed. However, when used as a processing aid in brewing, it is highly diluted and is present in the wort and beer as sodium and hydroxyl ions which are indistinguishable from those already present, derived from the raw materials. The EU's SCF *(SCF, 1991)* has set a Group ADI of "not specified" for the cations ammonium, calcium, magnesium, potassium and sodium.
- **Behaviour in brewing and residues:** Typical concentrations of sodium in beer are in the range 1 – 130mg/litre (average 80mg/litre) which is less than the recommended maximum of 200mg/litre for sodium in drinking water *(EU, 1998: WHO, 2011).*
- **Specific legislation:**
  - Sodium hydroxide is an authorised **food additive** in the EU, although it is not allowed as an additive in beer *(EU, 2008c).*
  - **Purity specifications** for sodium hydroxide used as a food additive are set by Regulation 231/2012 *(EU, 2012)* and the sodium hydroxide used in yeast washing should conform to these specifications.

3.8 Yeast nutrients

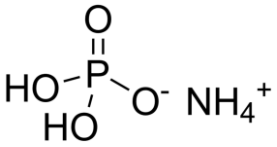
Note that there is no specific EU legislation on yeast nutrients. However, some EU countries such as Germany do not allow the use of yeast nutrients for beers brewed according to the Reinheitsgebot.

3.8.1 Ammonium salts

- **Chemistry:**

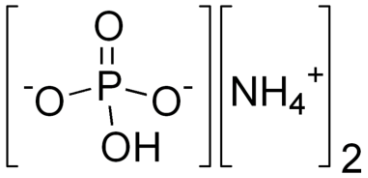


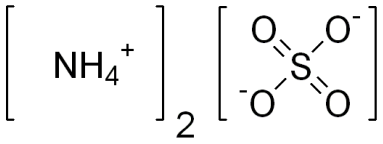
Name: ammonium chloride
Chemical Formula: NH_4Cl
CAS. No. 12125-02-9
EINECS: 235-186-4



Name: monobasic ammonium phosphate
Chemical Formula: $NH_4H_2PO_4$
CAS. No. 7722-76-1
EINECS: 231-764-5

Name: dibasic ammonium phosphate
Chemical Formula: $(NH4)_2HPO4$
CAS. No. 7783-28-0
EINECS: 231-987-8





Name: ammonium sulphate
Chemical Formula: $(NH_4)_2SO_4$
CAS. No. 7783-20-2
E No. E517
EINECS: 231-984-1

These ammonium compounds are highly soluble inorganic salts, with the sulphate and chloride being more rapidly dissociated than the mono- and di-basic ammonium phosphates. (Tribasic ammonium phosphate $(NH_4)_3PO_4$ is not stable and dissociates rapidly, releasing ammonia).

- **Use:** Ammonium chloride and sulphate and the mono- and di- basic ammonium phosphates can be used as yeast nutrients, either alone or in combination with other inorganic salts and organic nutrients such as amino acids. Tribasic ammonium phosphate is too unstable for commercial use. All are good sources of nitrogen. Ammonium sulphate is also a good source of sulphur (24% by weight), while the ammonium phosphates also supplies phosphorus, although these elements are less likely to be limiting in fermentations.
- **Toxicity:** Ammonium cations in food additives were evaluated by the SCF, who assigned a group ADI of "not specified" for ammonium, calcium, magnesium, potassium and sodium ions on the basis that they were all natural constituents of man, animals and plants and constituted the major electrolytes present in biological systems *(SCF, 1991).* Likewise, a Group ADI of "not specified" for chloride, carbonate and sulphate was set by the SCF on the same basis.
  In concentrated form, alkaline mono- and dibasic ammonium phosphates can be irritating to the skin and gastrointestinal tract but in dilute solution they are less toxic. Phosphates are not absorbed well from the gastrointestinal tract. The SCF regarded the main health risk for orthophosphates to be an imbalance between calcium, magnesium and phosphate metabolism and set a maximum Tolerable Daily Intake for orthophosphates and polyphosphates used as food additives of 70mg/kg body weight, calculated as phosphorus *(SCF, 1991).*
- **Behaviour in brewing and residues:** Yeast nutrients are added to the wort immediately prior to fermentation. Most of the substances added as yeast nutrients are taken up and metabolised by the yeast. The remaining ions are indistinguishable from those present naturally, derived from the raw materials and the brewing water.
- **Specific legislation:**
  - Ammonium sulphate is an authorised food additive in the EU although it is not permitted as an additive in beer. Purity specifications are set for food additive use and yeast nutrients should comply with these *(EU, 2012).* Ammonium sulphate is listed as a permitted yeast food for beers in Canadian legislation *(Health Canada, 2013)*

and also in the US Adjunct Reference Manual.

- Monobasic ammonium phosphate is listed as a permitted yeast food for beers in Canadian Legislation *(Health Canada, 2013)* and also in the US Adjunct Reference manual for Brewing.

3.8.2 Magnesium salts

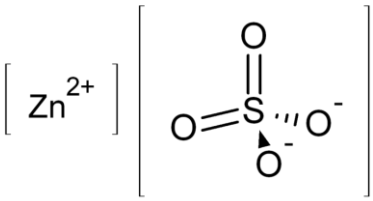
Name:	magnesium chloride
Chemical formula:	$MgCl_2$
CAS. No:	7786-30-3
E No.	E511
EINECS:	232-094-6

- **Chemistry:** magnesium is a divalent metal, classified as an alkaline earth, in the same group as calcium. In biological systems, magnesium and calcium are often affected by the same enzymes, and can be antagonistic, so that high concentrations of one can depress uptake of the other. Magnesium chloride is an inorganic salt of magnesium which dissolves readily in water to give a weak acid.
- **Use:** Several magnesium salts, including magnesium chloride, are authorised additives in the EU although they are not permitted for use in beer as additives *(EU, 2008c).* Magnesium is essential for human health, and is also essential for yeast. Magnesium is a cofactor in many enzyme systems, particularly for those enzymes involved in glycolysis. Thus magnesium is essential for the efficient conversion of sugar to alcohol *(Gibson, 2011).* Since magnesium and calcium are taken up by yeast using the same mechanisms, high concentrations of calcium will reduce the rate of uptake of magnesium, possibly resulting in sub-optimal levels of magnesium in the cell. Magnesium is therefore sometimes added to wort as a yeast nutrient prior to fermentation. Supplementation of worts with magnesium as concentrations of up to 500 mg/litre have been found to improve the uptake of sugars and the production of ethanol *(Rees & Stewart, 1997, 1999).* Magnesium ions have also been shown to protect yeast cells from the toxic effects of ethanol, and so may be important in high gravity fermentations *(Walker, G.M., 1998).*
- **Toxicity:** The SCF have established a group ADI of “not specified” for the cations calcium, magnesium, potassium, sodium and ammonium, on the basis that these ions are occur naturally in man, plants and animals and provide the basis of major biological electrolyte systems *(SCF, 1991).* By the same argument, a Group ADI of “not specified” was set for the anions chloride, sulphate and carbonate *(SCF, 1991).*
- **Use in brewing and residues:** The concentration of magnesium in wort is typically in the range 50 – 90 mg/litre which is probably sub-optimal for many brews *(Gibson, 2011).* Supplementation rates may be up to 500 mg/litre. Much of this is taken up by the yeast. The range of magnesium concentrations reported in beers is very wide, from < 100 to over 200mg/litre, but typical levels are less than 100mg/litre, which is significantly lower than the daily requirement for magnesium.
- **Specific legislation**
  - Several magnesium salts, including magnesium phosphate and chloride, are authorised additives in the EU, although they are not permitted as additives for beer *(EU, 2008c).*
  - Purity criteria are set for these salts for use as additives and should be complied with for use as yeast nutrients *(EU, 2012).*

- The daily requirement for magnesium is 375mg/day (for labelling and nutritional claims purposes) *(EU, 2011b).*

3.8.3 Zinc salts

- **Chemistry:**



Name: zinc sulphate
Chemical Formula: $ZnSO_4$
CAS. No. 7733-02-0
EINECS: 231-793-3

Zinc is a post-transitional metal with an atomic weight of 65.37. It reacts readily with dilute acids and alkalis to form salts such as zinc sulphate and zinc chloride, most of which are very soluble in water. In biological systems zinc exists as the ion Zn^{2+}.

- **Use:** Many zinc salts, including the acetate, chloride, oxide and sulphate, are included in the list of ingredients which may be used in the manufacture of foods for particular nutritional uses and in food supplements in the EU *(SCF, 2003b).* Zinc is also an essential nutrient for yeast, being a catalytic or structural co-factor in many essential enzymes, including those needed for glycolysis and alcohol synthesis *(Gibson, 2011).*Although barley and malt normally contain between 18 and 34mg/kg of zinc *(Cejka et al, 2005: Vico, 2006),* much of this is not extracted during mashing and remains with the brewers' grains. Zinc can also be significantly reduced in cereals grown on zinc-depleted soils, which are common in some geographical areas. Brewery worts can contain between 0.1 and 5mg/litre of zinc *(Gibson, 2011).* For standard gravity fermentations, a wort concentration of 0,2 mg/litre is normally sufficient. Tolerance to higher concentrations is affected by manganese concentration and yeast strain.
- **Toxicity:** Zinc is an essential nutrient for humans, being present in all tissues and fluids in the body. The total content of zinc in the body is between 2 and 4g, although it is not stored in the body *(SCF, 2003b).* Nevertheless, excess intake can have adverse effects. Acute toxicity is rare, but chronic intake of excess amounts (usually taken as zinc supplements in quantities of up to 300mg/day) can have adverse effects, particularly on the blood chemistry. The SCF have recommended a Tolerable Upper Limit for adults (including pregnant and lactating women) of 25mg/day *(SCF, 2003b).*
- **Behaviour in brewing and residues:** In wort, zinc can bind to amino acids in protein and become unavailable for yeast. The timing of addition is therefore important, with addition at the same time as pitching appearing optimal *(Taidi et al, 2000).* Most of the zinc present naturally in the wort (derived from the malt) or added during fermentation is either taken up by the yeast or lost in the brewers' grains, trub or cold breaks. In brews spiked with zinc, less than 10% of added zinc survives into the beer *(Leubolt et al, 1992: Mader et al, 1997: Vecseri-Hegyes et al, 2005).* Concentrations of zinc in beer are typically around 0.01-0.02 mg/litre. These are very low compared with the amounts which can cause health problems.

- **Specific legislation:**
  - In the EU, nine zinc salts, including zinc acetate, zinc chloride and zinc sulphate may be used as ingredients in foods for special purposes, including foods for babies and infants, foods for special medical purposes and foods intended as a complete meal replacement. The concentrations allowed have yet to be determined *(EU, 2013).*
  - The recommended daily intake of zinc for adults (for food labelling and claims purposes) is 10mg/day *(EU, 2011b).*
  - In the US, zinc chloride and zinc sulphate are listed in the adjunct reference manual of the Beer Institute as permitted nutrients used in brewing *(TTB, 1995).* .
  - In Canada, zinc sulphate is listed as a permitted yeast nutrient for brewing *(Health Canada, 2013).*

3.8.4 Commercial yeast foods

The composition of these commercial products is often unspecified, but most contain a mixture of minerals (such as zinc and magnesium), anions (such as sulphate or phosphate) and amino acids. Some also contain vitamins. Some are water soluble autolysates of brewers yeast and these are generally acceptable under the Reinheitsgebot. Although these are potentially excellent sources of nutrients for yeast, the main problem is that if they are derived from spent yeast, their actual composition is undefined, so there could be variations from batch to batch. Other products are derived from specially grown yeast cultures and these will be more reproducible.

4. HACCP for use of processing aids

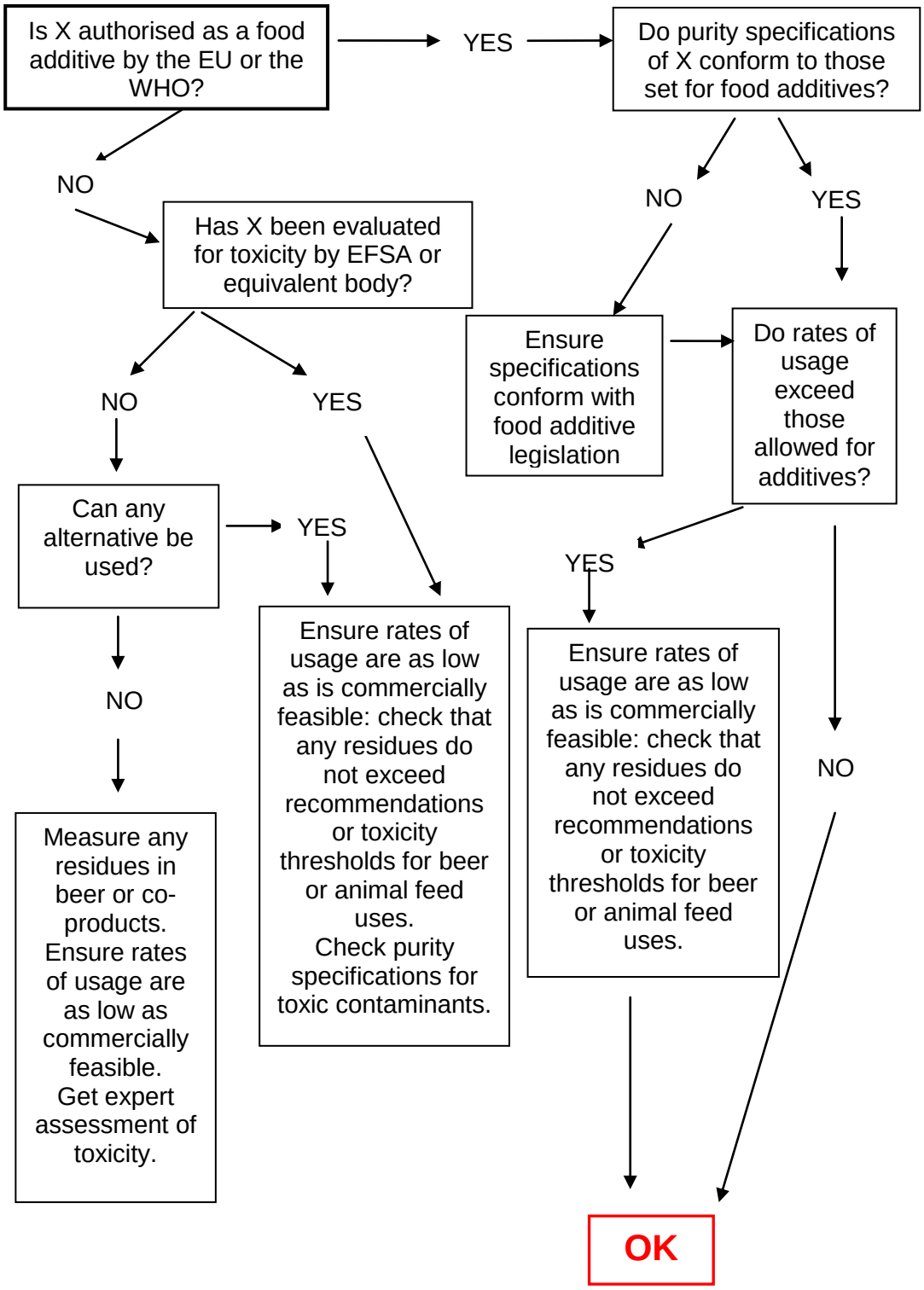
Processing aids are not, by their nature, likely to be hazardous in use. However, a HACCP-type decision tree which can be used to check that potential risks are addressed is given on the next page. This can be summarised as follows:

- **Food additives authorised in the EU:** can be used as processing aids in brewing provided purity specifications and any relevant restrictions are complied with (subject to any national legislation).
- **Food additives authorised by WHO but not in the EU:** can be used as processing aids in brewing provided any WHO purity specifications and any restrictions by WHO or EFSA are complied with (subject to national legislation).
- **Substances not authorised by EU or WHO:** user is responsible for checking for any toxicity concerns expressed by other competent bodies (eg US FDA, national experts).

Note 1: it is the responsibility of the user to ensure that any processing aids used, whether authorised by EU, WHO or other body, do not have any adverse effects on his/her brewing process or the quality of finished products.

Note 2: any national legislation on processing aids must be complied with regardless of whether substances are authorised as additives.

Figure 1. Decision tree for processing aid X



5. References

ACC, 2013. Activated Carbon Consortium – Status of preparation for the registration.
http://www.reachactivatedcarbon.eu/status.html

Ajinomoto, 2007.
http://www.natural-specialities.com/natural-specialities/en/8443-brewery.html

Aschengreen, N.H. and Jepsen, S., 1992. *Proc. Conv. Inst. Brew*. (Aust. N.Z. Sect.), Melbourne, (22), 80-83.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=42509

Aucott, J.N. et al, *Invasive infection with Saccharomyces cerevisiae*; report of three cases and review. *Rev. Infect. Dis.,* 1990, **12,** 406-411.
http://cid.oxfordjournals.org/content/12/3/406.short

Austria, 2013. Codex Alimentaruis Austriacus.
http://www.lebensmittelbuch.at/
Chapter on bee (1998), http://www.lebensmittelbuch.at/bier/

Baker, C.D. and Boddy, M.R., 1977. *J. Inst. Brew.,* May/June 1977, **83(3),** 158-159. "Determination of silicone antifoam in beer".

Bamforth, C., 2008. *Food Sci. Technol*., 22(4), 12-14.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=76408

Barth-Haas Group., 2012. Materials Safety Data Sheet for HopAid.
http://www.barthhaasgroup.com/johbarth/images/pdfs/specs/msds/HopAid_GHS_v1.pdf

Basildon Chemicals, Antifoam FD20PK; Product Datasheet.
http://www.baschem.co.uk/Downloads/ProductDatasheets/FD20PK(AFE)%20with%20BC%20logo.pdf

Batchvarov, V., Velinov, D. and Marinova, G., 1995. *Monatsschr. Brauwiss.,* **48(11/12),** 397-402.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=49717

Belgium, 2011. Comite scientifique De l'agence federale pour la securite de la chaine alimentaire. Evaluation des risques liés aux substances chimiques et Biotechnologiques qui entrent en contact avec la chaîne alimentaire (dossier Sci Com N° 2010/08: auto-saisine).
http://www.afsca.be/denreesalimentaires/circulaires/_documents/2013_03_13_annexe3_avis_13-2011_FR.pdf

Biering, J., Bilge, D. and Folz, R., 2013. Brau. Forum (Int. VLB Ed.), *16 Sept. 2013, 16-17.*
BFBi, 2006a. Brewing, Food and Beverage Industry Suppliers Association and The Brewers of Europe: Application for exemption from labelling for isinglass used as a fining agent in brewing.

BFBi, 2006b. Code of Good Manufacturing Practice for Isinglass low in

parvalbumin. *(available from the BFBi).*

Botanix – HopAid Antifoam.
http://www.botanix.co.uk/antifoam

Botanix Ltd., Marriott, R.J., 2008. Br. Pat. Appl. GB 2444359 A.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=76189
http://www.botanix.co.uk/antifoam

Brewers of Europe, 2012. The Brewers of Europe Report on Residues of Processing Aids in Brewing Co-products.

Brewers Supply Group web site. Wort clarification products: Application.
http://www.brewerssupplygroup.com/WortClarification.html

Buckee, G.K., Dolezil, L., Forrest, I.S. and Hickman, E., 1976. *J. Inst. Brew.,,* July/Aug. 1976, **82(4),** 209-211.

Bulgaria, 2000. Ordinance on Requirements for Labelling and Presentation of the Foodstuffs adopted by Decree No 136 of 19.07.2000, published in State Gazette 62/28.07.2000 and amended, Art 18.
http://ec.europa.eu/food/food/enlargement/reports/bulgaria2005.pdf

CAC, 1999. Codex Inventory of Processing Aids. CAC-MISC 3
http://std.gdciq.gov.cn/gssw/JiShuFaGui/CAC/CXA_003e.pdf

CAC, 2010a. Codex Standard CAC/GL 75-2010. Guidelines on substances used as processing aids.

CAC, 2010b. Inventory of substances used as processing aids (IPA), updated list. Presented to the Codex Committee on Food Additives, 42nd session, Beijing, March 2010.
http://www.conal.gov.ar/Notas/Ingresadas/2010_02Feb_15_NotaLANXESS_03.pdf

CAC, 2012. Database on processing aids – criteria for entry into the database. Codex Committee on Food Additives, 45th Session, Beijing, March 2013.
ftp://ftp.fao.org/codex/meetings/ccfa/ccfa45/fa45_18e.pdf

CAHG. Codex Alimentarius Hungaricus Guideline No 2-106 BEERS with distinctive quality indication, II and Codex Alimentarius Hungaricus Guideline No 2-702 Beer Para II (1).

Casey, T.R. and Bamforth**,** C.W. 2010, *J. Sci. Food Agric*., **90(5),** 784-788.

Cejka, P., Kellner, V., Horak, T., Culik, J. and Jurkova, M., 2005, *Kvasny Prum.,***51(2),** 52-55.

CFR, 2013a. US Code of Federal Regulations, Title 21 CFR Part 173: 340.
http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=173.340

CFR, 2013b. US Code of Federal Regulations, Title 21 CFR 184

http://www.gpo.gov/fdsys/pkg/CFR-2012-title21-vol3/pdf/CFR-2012-title21-vol3-part184.pdf

Clemons, K.V., McCusker,J.H., et al, Comparative pathogenisis of clinical and nonclinical isolates of *Saccharomyces cerevisia*e. *J. Infect. Dis.,* 1994, **169,** 859-867.
http://jid.oxfordjournals.org/content/169/4/859.short

Cyprus. State General Laboratory : food legislation.
http://www.moh.gov.cy/moh/sgl/sgl.nsf/page09_en/page09_en?OpenDocument#1

Czech, 1997. Decree of the Ministry of Agriculture 335/1997 implementing § 18 a), d), h), i), j) and k) of Act No. 110/1997 Coll. on foodstuffs and tobacco products and on amendments and additions to some related Acts, applicable to soft drinks and concentrates for preparation of soft drinks, fruit wines, other wines and mead, beer, surgical spirit, liqueurs and other alcoholic drinks, fermented vinegar and yeast (as amended by Decree No. 45/2000, Decree No. 57/2003, Decree No. 289/2004 and Decree No. 115/2011 (update to beer types and definitions).

Denmark, 2005. Bekendtgørelse om mærkning m.v. af fødevarer BEK nr 1308 af 14/12/2005 Kapitel 6 §17 Stk. 3.
https://www.retsinformation.dk/Forms/R0710.aspx?id=31582

DG-HCP, 2000. Reports for Scientific Cooperation (SCOOP). Study of enzymes used in foodstuffs and collation of data on their safety. Annexes.
http://ec.europa.eu/food/fs/scoop/7.4.2_en.pdf

EFSA, 2004. Opinion of the Scientific Panel on Dietetic products, nutrition and allergies [NDA] related to the Tolerable Upper Intake Level of Silicon.
http://www.efsa.europa.eu/en/efsajournal/pub/60.htm

EFSA, 2005. Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Semicarbazide in food .
http://www.efsa.europa.eu/en/efsajournal/pub/219.htm

EFSA, 2006. Opinion of the Scientific Panel on biological hazards (BIOHAZ) on the “Quantitative assessment of the Human BSE risk posed by Bovine Vertebral Column including Dorsal Root Ganglia with respect to residual BSE risk”
http://www.efsa.europa.eu/en/efsajournal/pub/359.htm

EFSA, 2008. Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to use of formaldehyde as a preservative during the manufacture and preparation of food additives .
http://www.efsa.europa.eu/en/efsajournal/pub/415.htm

EFSA, 2009. Scientific Opinion: Calcium silicate and silicon dioxide/silica gel added for nutritional purposes to food supplements. *EFSA J,* 2009, **1132,** p1-24.

http://www.efsa.europa.eu/en/scdocs/doc/ans_ej1132_Inorganicsiliconsources_op_en.pdf?ssbinary=true

EFSA, 2012. Call for scientific data on miscellaneous food additives permitted in the EU and belonging to several functional classes.
http://www.efsa.europa.eu/en/dataclosed/call/120706a.htm

EFSA, 2013. Scientific Opinion on the maintenance of the list of QPS biological agents intentionally added to food and feed (2013 update).EFSA Journal 2013;11(11):3449.
http://www.efsa.europa.eu/en/efsajournal/doc/3449.pdf

EFSA, 2014. Scientific Opinion on the safety assessment of the active substances, sodium erythorbate, sodium carbonate, sodium bicarbonate, iron sulphate, activated carbon, cellulose, calcium hydroxide, calcium chloride and water, for use as active system in food contact materials. *EFSA Journal* 2014;12(2):3571.
http://www.efsa.europa.eu/en/efsajournal/pub/3571.htm

Englemann, J. and Reichert, R., 1991. *Brew. Guardian*, **120(9),** 20, 22.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=40604

EU, 1998. Council Directive 98/83.EEC on the quality of water intended for human consumption.
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01998L0083-20090807&rid=1

EU, 1999. 1999/724/EC: Commission Decision of 28 October 1999 amending Annex II to Council Directive 92/118/EEC laying down animal health and public health requirements governing trade in and imports into the Community of products not subject to the said requirements laid down in specific Community rules referred to in Annex A (I) to Directive 89/662/EEC and, as regards pathogens, to Directive 90/425/EEC (notified under document number C(1999) 3493).
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31999D0724&rid=2

EU, 2002. Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:031:0001:0024:EN:PDF

EU, 2004. Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC (as amended, 2009).
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2004R1935:20090807:EN:PDF

EU, 2008a. Regulation (EC) No 1331/2008 of the European Parliament and of the Council of 16 December 2008 establishing a common authorisation procedure for food additives, food enzymes and food flavourings. *Off. J.*, **L 354,** 31.12.2008, p. 1–6.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1331:EN:NOT

EU, 2008b. Regulation (EC) No 1332/2008 of the European Parliament and of the Council of 16 December 2008 on food enzymes and amending Council Directive 83/417/EEC, Council Regulation (EC) No 1493/1999, Directive 2000/13/EC, Council Directive 2001/112/EC and Regulation (EC) No 258/97. *Off. J.,* **L 354**, 31.12.2008, p. 7–15.
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008R1332-20121203&from=EN

EU, 2008c. Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives. *Off.J.* **L 354**, 31.12.2008, p. 16.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2008R1333:20111202:EN:PDF

EU, 2008d. Commission Directive 2008/128/EC of 22 December 2008 laying down specific purity criteria concerning colours for use in foodstuffs *Off. J.*, **L 6**, 10/01/2009, p. 20–63.
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0128-20110207&rid=1

EU, 2011a. Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives. *Off. J.* **L295,** p1. 12.11.2011.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:295:0001:0177:EN:PDF

EU, 2011b. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004. *Off. J.* **L304,** p18:22.11.2011.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:304:0018:0063:EN:PDF

EU, 2011c. Commission Regulation 10/2011 on Plastic materials and articles intended to come into contact with food. *Off. J.,* **L12,** 15.1.2011, p1.
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02011R0010-20130101&rid=1

EU, 2012. Regulation (EU) No 231/2012 of 9 March 2012 laying down specifications for food additives listed in Annexes II and III to Regulation (EC) No 1333/2008 of the European Parliament and of the Council
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:083:0001:0295:EN:PDF

EU, 2013. Regulation No. 609?2013 of the European Parliament and of the Council of 12 June 2013 on food intended for infants and young children, food for special medical purposes, and total diet replacement for weight control.
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0609&from=EN

FAO, 1992. JECFA Monographs, Polydimethylsiloxane.
http://www.fao.org/ag/agn/jecfa-additives/specs/Monograph1/Additive-315.pdf

FAO, 1997. JECFA Monographs. Sodium alginate.
http://www.fao.org/ag/agn/jecfa-additives/specs/Monograph1/Additive-388.pdf

FAO, 2009. JECFA Monographs. Tannic acid.
http://www.fao.org/ag/agn/jecfa-additives/specs/monograph7/additive-454-m7.pdf

FAO, 2010. JECFA Monograpohs. Activated carbon.
http://www.fao.org/ag/agn/jecfa-additives/specs/monograph10/additive-006-m10.pdf

FCC, 2013. Food Chemicals Codex Online.
http://online.foodchemicalscodex.org/online/login

Finland, 2011. 1020/2011: Maa- ja metsätalousministeriön asetus valmistuksen apuaineista elintarvikkeissa (The Ministry of Agriculture and Forestry's statute on processing aids in foodstuffs)
http://www.finlex.fi/fi/laki/alkup/2011/20111020

Ford, Y.-Y., Westwood, K.T., Gahr, A., Rajca Ferreira, A., Wolinska, K., Lad, M., Wolf, B. and Foster, T., 2012. *Tech. Q. Master Brew. Assoc. Am.,* **49(1),** *3-10.*
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=86472

France, 2011. Décret n° 2011-509 du 10 mai 2011 fixant les conditions d'autorisation et d'utilisation des auxiliaires technologiques pouvant être employés dans la fabrication des denrées destinées à l'alimentation humaine.
http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000023982083&dateTexte=&categorieLien=id

France, 2014. Arrêté du 19 octobre 2006 relatif à l'emploi d'auxiliaires technologiques dans la fabrication de certaines denrées alimentaires.NOR: ECOC0600115A
Version consolidée au 22 mars 2014
http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000271061&dateTexte=

FSANZ, 2011. Australia New Zealand Food Standards Code. Standard 1.3.1, Food Additives. Schedule1, 14.2.1.
http://www.comlaw.gov.au/Details/F2011C00892/Html/Volume_2

Fumz, N. and Schaft, H., 1995. Japanese. Pat. Appl. JP 07203941.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=49488

Funnell, N., 2002. *New Brewer,* p33.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=64159

Germany, 1974. Gesetz über den Verkehr mit Lebensmitteln, Tabakerzeugnissen, kosmetischenMitteln und sonstigen Bedarfsgegen-ständen (Law on foodstuffs, tobacco products, cosmetics and other consumer goods),
http://www.loerrach-landkreis.de/servlet/PB/show/1458001/LebensmittelBedgesetz.pdf

Gibson, B.R., 2011. *J. Inst. Brew.,* **117(3),** 268-284.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=84440

Gjertsen, P. and Schouboe, A., 1974. *Brew. Dig*., **49(1),** 52-54, 56-59, 62.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=26275

Gough, A.J.E., 1995. *Tech. Q. Master Brew. Assoc. Am.,* **32(4),** 195-200.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=49376

Greece. The Supreme Chemical Council of the State.
http://www.gcsl.gr/index.asp?a_id=3

Grutzmacher, J., 1990. *Lebensmittelindustrie*, **37(4),** 159-162.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=38895

Health Canada, 2013. List of permitted yeast foods.
http://www.hc-sc.gc.ca/fn-an/securit/addit/list/14-yeast-levures-eng.php

Hickman, D., Sims, T.J., Miles, C.A., Bailey, A.J., de Mari, M. and Koopmans, M., J. 2000. *Biotechnol*., **79(3),** 245-257.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=60505

HSE, 2011. Health and safety Executive: EH40/2005 Workplace Exposure Limits (amended 2011).
http://www.hse.gov.uk/pubns/priced/eh40.pdf

Hungary, 2004. Regulation 19/2004. (II.26) FVM-ESZCSM-GKM on food labelling and amendments, §7(5)b).

Imerys Filtration Minerals Inc., Wang, B., 2013. Int. Pat. Coop. Treaty Appl. WO 2013096578 A1, 2013.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=89594

Ireland, 2013. Food legislation
http://www.fsai.ie/legislation/food_legislation.html

Italy, 1994. Ministerial Decree of 1st of July 1994
http://www.ismea.it/flex/AppData/Redational/Normative/20020520000100278.pdf

Italy, 1996 (last modified, 2006). Regolamento concernente la disciplina degli additivi alimentari consentiti nella preparazione e per la conservazione delle sostanze alimentari in attuazione delle direttive n. 94/34/CE, n. 94/35/CE, n. 94/36/CE, n. 95/2/CE e n. 95/31/CE. (I) (pubbl. in Suppl. Ord. *Gazz. Uff.* n. 96 del 24 aprile 1996). ALLEGATO XIV
http://www.legapesca.coop/Documenti/qualita/DM_27_02_96_209_Disciplina_additivi_alimentari.pdf

JECFA, 2007. FAO JECFA Monographs 4. Carrageenan
http://www.fao.org/ag/agn/jecfa-additives/specs/monograph4/additive-117-m4.pdf

JECFA, 2008. 69th meeting of the Joint Expert Committee on Food Additives and Contaminants. WHO Food Additives Series 60.
http://www.inchem.org/documents/jecfa/jecmono/v60je01.pdf

Johnson, D., 2009. July/August, fNew Brewer.
http://www.birkocorp.com/brewery/white-papers/antifoams/

Jones,, H.L., Larnach, K.M., Gillon, J.E. and Mussche, R. 1994, *Proc. Aviemore Conf. Malt. Brew. Distill.,* **4**, 353-356.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=50273

Kaminishi, H. et al, Degradation of humoral host defences by *Candida albicans* proteinase. *Infect. Immun.,* 1995, **63,** 984-988.
http://iai.asm.org/content/63/3/984.short

Kavanagh, K and Murphy, A., Baker's yeast – friend or foe? Food Ireland 2001, p9-10.

Klopper,W.J., Angelino, S.A.G.F., Tuning, B. and Vermeire, H.A., 1986, *J. Inst. Brew.,* **92,** 225-228.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=10829

Lallemand UK Ltd., Littlewood, J., 2008. Eur. Pat. Appl. EP 1955750 A1.
http://www.google.com/patents/EP1955750A1?cl=en

Leubolt, R., Huber, C., Urban, A. and Puspok, J., 1992. *Mitt. Oesterr. Getraenke Inst.,* **46(7/8),** 80-83.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=43009

Luxembourg, 1994. Règlement grand-ducaldu27janvier1994relatifàlabière.
http://www.legilux.public.lu/leg/a/archives/1994/0011/a011.pdf#page=2

Mader, C., Sommer, G. and Thurl, S., 1997, *Monatsschr. Brauwiss.,* **50(7/8),** 138-141.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=53483

McCusker, J.H. et al, Genetic characterisation of pathogenic *Saccharomyces cerevisiae* isolates. *Genetics,* 1994a, **136,** 1261-1269.
http://www.genetics.org/content/136/4/1261.short

McCusker, J.H. et al, *Saccharomyces cerevisiae* virulence phenotype as determined with CD-1 mice is associated with the ability to grow at 42°C and form pseudohyphae. *Infect. Immun.* 1994b, **62,** 5447-5455.
http://scholar.google.co.uk/scholar?q=McCusker%2C+virulence&btnG=&hl=en&as_sdt=0%2C5

Methner, F.J., Kuntz, T., Weitstock, P.C., Marinoff, M. and Gaulke, M., 2013. *Proc. Eur. Brew. Conv., Luxemburg.*
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=89475

Moll, M., 2004. *Cerevisia Belg. J. Brew. Biotechnol.,***29(4),** 199-210.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=68300
Moll, M. and Lenoel, M., 1997. *Cerevisia Belg. J. Brew. Biotechnol*., **22(3),** 44-50.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=53714

Müller, V., Jung, T. and Otto, R., 2013. Brauindustrie, **98(9***),* 50-52.
http://beerknowledge.campdenbri.co.uk/edit/brew.aspx?id=89865

Murphy, A. and Kavanagh, K., Emergence of *Saccharomyces cerevisiae* as a human pathogen. Implications for biotechnology. *Enz. Micro Tech.,* 1999, **25(7),** 551-557.
http://www.sciencedirect.com/science/article/pii/S0141022999000861

Mussche, R., 1990. Proc. Conv. Inst. Brew. (Aust. N.Z. Sect.), *Auckland,* **21,** 136-140.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=38499

Mussche, R.A. and De Pauw, C. 1998, *Proc. Conv. Inst. Brew. (Asia Pacific Sect.), Perth,* **25, ,** 125-130.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=55588

Narziss, L., Reicheneder, E. and Iwan, H.-J., 1986. *Monatssch. Brauwiss.,* **39(1),** 4.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=7935

OECD, 2005. OECD SIDS, Persulphates.
http://www.chem.unep.ch/irptc/sids/OECDSIDS/Persulfates.pdf

OECD, 2001. OECD SIDS, Citric acid.
http://www.inchem.org/documents/sids/sids/77929.pdf

Ohno, T. and Takahashi, R., 1986. *J. Inst. Brew.,* **90(1),** 84-87.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=9320

ONSedge 2010. Knowledge Report, Invasive Fungal Infections.
http://www.onsedge.com/pdf/IFIKnowledgeReport.pdf

Phypers, B. and Pierce, J.M.T., 2006. *Continuing Education in Anaesthesia, Critical care and Pain,* **6(3),** 128-132.
http://ceaccp.oxfordjournals.org/content/6/3/128.full

Portugal, 1996. Ministerios da Economia e da Agricultura, do desenvolvimento Rural e das Pescas Portaria no. 1/96 de 3 de Janeiro and amendments, Anexo 1.

Priest, F.G. and Stewart, G.G., ed. "Handbook of Brewing", 2006.

Raja Mohd Hafidz, R.N., Yaakob, C.M., Amin, I. and Noorfaizan, A., 2011. *Int. Food Res. J.,* **18,** 813-817.
http://ifrj.upm.edu.my/18%20(02)%202011/(48)%20IFRJ-2010-159.pdf

Rees, E.M.R. and Stewart, G.C., 1997. *J. Inst. Brew.,* **103, 287-291.**
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=53704

Rees, E.M.R. and Stewart, G.C., 1999. *J. Inst. Brew.,* **105, 211-217**
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=57977

SCF, 1978. Reports of the Scientific Committee on Food on Emulsifiers, Stabilisers, Thickeners and gelling agents. , 7th Series.
http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_07.pdf

SCF, 1991. Reports of the Scientific Committee for Food, 25th series.
http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_25.pdf

SCF, 2002. Opinion of the Scientific Committee on Food on specifications for gelatin in terms of consumer health.
http://ec.europa.eu/food/fs/sc/scf/out122_en.pdf

SCF, 2003a.EU Scientific Committee on Food. Opinion on Carrageenan.
http://ec.europa.eu/food/fs/sc/scf/out164_en.pdf

SCF, 2003b. Opinion of the Scientific Committee for Food on the Tolerable Upper Intake level for zinc.
http://ec.europa.eu/food/fs/sc/scf/out177_en.pdf

SCOEL, 2012. Recommendations from the Scientific Committee on Occupational Exposure Limits for Acetic Acid.
ec.europa.eu/social/BlobServlet?docId=7877&langId=en

SCOGS, 2013. Select Committee on GRAS Substances: Perlite.
http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/SCOGS/ucm260952.htm

Shoham, S. and Marr, K.A., 2012. *Future Microbiol.* **7(5):**639-655.
http://www.medscape.com/viewarticle/763807

Siebert, K.J. and Lynn, P.Y., 1997. *J. Am. Soc. Brew. Chem.,* **55(2),** 73-78.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=52716

Simpson, W.J., 1987a. J. Inst. Brew., **93(4),** 313-318.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=29734

Simpson, W.J., 1987b. *J. Inst. Brew.,* **93(5),** 405-406.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=29919

Simpson, W.J. and Hammond, J.R.M., 1989. J. Inst. Brew., **95(5),** 347-354.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=35965

Sinclair, A. and Hallam, T.R., 1971, *Analyst,* **96(1139),** 149-154,
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=24112

Siristova, L. and Melzoch, K., 2009. *Kvasny Prum*., **55(1),** 16-20.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=76906

Slovak Republic, 2008. Legal Act 04650/2008-OL of 27 February 2008.

Slovak Republic, 2014. Decree 30/2014 of January 2014 on requirements for drinks. Slovakian Food Codex, Part3, head 25, Drinks, 3(7).

Slovenia, 2004. UL No. 43/2004, 1929, article 3 point 2.
http://www.uradni-list.si/1/content?id=48650

Spain. 1983. Boletín Oficial del Estado» de 21 de enero de 1983.
https://www.boe.es/diario_boe/txt.php?id=BOE-A-1983-2211

Spain, 1995 Real Decreto 53/1995, de 20 de enero, por el que se aprueba la Reglamentación técnico-sanitaria para la elaboración, circulación y comercio de la cerveza y de la malta liquida.
https://www.boe.es/diario_boe/txt.php?id=BOE-A-1995-3394

Switzerland, 2005. 817.02 "Lebensmittel- und Gebrauchsgegenständeve-rordnung" from 23 November 2005
http://www.admin.ch/opc/de/classified-compilation/20050153/index.html

Taidi, B., Hoogenberg, B., Kennedy, A.I. and Hodgson, J.A., 2000. Tech. Q. Master Brew. Assoc. Am., **37(4),** 431-434.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=61069

TTB, 1995. Industry Circular No. 95-6
http://www.ttb.gov/industry_circulars/archives/1995/95-06.html

TTB, 2014. Alcohol and Tobacco, Tax and Trade Bureau: Beer Industry, Recently approved adjuncts.
http://www.ttb.gov/beer/approved_adjuncts.shtml

Van Landschoot, A., 2009. *Proc. Eur. Brew. Conv., Hamburg, 2009, (abstract published online - full text not published).*
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=78584

Vecseri-Hegyes, B., Fodor, P. and Hoschke, A., 2005, *Acta Aliment.,* **34(4),** 373-380.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=77384

Vico, I. 2006, *Cerveza Malta*, **43(2),** 25-27.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=75739

Walker, G.M., 1998. *J. Am. Soc. Brew. Chem.,* **56,** 109-113.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=56299

Weissenbach, M.J., 2000, *Brauwelt Int., **18(2),*** 144-147, 150-154.
http://beerknowledge.campdenbri.co.uk/view/brew.aspx?id=59603

WHO, 1984. WHO Food Additive Series No. 19, Carageenan and furcellaran.
http://www.inchem.org/documents/jecfa/jecmono/v19je05.htm

WHO, 1993. WHO Food Additive Series No. 33. Lysozyme
http://www.inchem.org/documents/jecfa/jecmono/v30je04.htm

WHO, 2002. World Food Additive Series No. 48. Carrageenan and processed Euchema seaweed.
http://www.inchem.org/documents/jecfa/jecmono/v48je08.htm

WHO, 2011. World Health Organisation. Guidelines for drinking water quality, 4th edition, 2011. Chapter 12.
http://www.who.int/water_sanitation_health/publications/2011/9789241548151_ch12.pdf?ua=1

Part 4. Frequently Asked Questions

Q1. What are processing aids?
A1. Processing aids are substances which can be used to help with the manufacture of food and beverages but which have no technical function in the final food product.

Q2. Why are processing aids used in beer?
A2. Processing aids can be used for several purposes in brewing. For example, enzymes can be used to help break down malt and convert the starch into sugars which the yeast can ferment into alcohol. Filtration aids can be used to remove particles of yeast and protein which make the beer cloudy. Yeast itself, although essential for fermentation, is classified as a processing aid because it has no function in the finished beer (except for certain special beer types where extra yeast is added to encourage a second fermentation in the bottle).

Q3. Does beer contain processing aids?
A3. Many processing aids, such as filter aids which are insoluble inert materials, are removed entirely from the beer and leave no residues. Others, such as the mineral salts added to adjust the acidity or alkalinity of the beer during its manufacture, are identical to those salts present naturally in the beer, derived from the malt and the brewing water.

Q4. Are processing aids declared on the label?
A4. No. Under EU law, processing aids do not need to be declared on the label unless they are made from or with listed allergens.

Q5. But I have seen many food labelled with the sort of substances you say are used as processing aids in beer.
Q5. Many of the substances used as processing aids in brewing are allowed as additives in many other foods. Under EU law, if an ingredients list is given, even if voluntarily, any additives used must also be declared on the label.

Q6. I have heard that isinglass is used in beer and is made from fish. Isn't that allergenic?
A6. No. Isinglass is exempted by the EU from triggering allergen labelling. It is certainly used in the manufacture of some beers, to help clarification (removal of proteins which cause cloudiness. Clinical trials have been carried out with people known to be sensitive to fish and these have demonstrated that beers fined with isinglass do not trigger allergenic reactions.



The Brewers of Europe

Campden BRI
food and drink innovation

The Brewers of Europe