# Technical Information Sheet

## Unmalted Cereals
## Prepared for
## The Brewers of Europe
## by

# BRI
## (one of the Campden BRI group of companies)

***Compiled by***
***E. Denise Baxter***
***I.Ormrod***

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## Contents

# Part 1.

## Non-technical summary

- Unmalted cereals are used in brewing to supplement or in some cases to partially or totally replace the malt grist. They, with other malt grist substitutes are often referred to as brewing adjuncts.
- Specific cereals may be used to provide desirable qualities in the beer, for example, flavour, colour, clarity, foam or physical stability.
- Wheat, rye and oats are used in many traditional beers in Europe.
- Starch-enriched fractions of maize and rice are often used to improve flavour stability in lighter flavoured beers.
- Use of unmalted cereals allows a wider range of cereals to be used as raw materials, meaning that local cereals can be utilised. This is particularly important in areas where good quality malt is expensive or difficult to obtain.
- Unmalted cereals are used in a variety of different forms including grits (coarser or finer milling fractions), micronized, torrefied or flaked products (heat treated to partially or completely gelatinise the starch) and flours.
- Different cereals show different likelihoods of producing certain mycotoxins. For example, maize can produce fumonisins, which are rarely found in wheat or barley. Oats are much more likely to produce T-2 and HT-2 toxins than are wheat or barley.
- The climate can also affect the type of mycotoxins produced. For example, aflatoxins are rarely found in grain grown in temperate regions, but are more prevalent in grains from hotter areas, such as sorghum.
- Different cereals also vary in their ability to accumulate arsenic and heavy metals. For example, rice tends to accumulate arsenic from the soil more than other cereals.
- In areas of heavy industry, arsenic and heavy metals can be present in the atmosphere and can contaminate growing crops. Cereals grown in areas of heavy industry are particularly at risk of this type of contamination.
- In general, the risk posed by mycotoxins is largely the same for unmalted and malted cereals. However, some fungal toxins are significantly reduced during steeping, so unmalted cereals may contain higher concentrations of these toxins than malted cereals from a similar source.
- Both unmalted and malted cereals are screened to remove physical contaminants such as foreign seeds etc or inorganic extraneous matter such as stones or sand. Unmalted cereals could be slightly more at risk than malted cereals, since the latter undergo screening twice, both before and after malting.
- Some countries, especially in the EU, set a minimum amount of malt which must be used in brewing recipes.

# Part 2.
# Technical Summary

- Unmalted cereals, also called adjuncts, are used in brewing to supplement or in some cases to partially or totally replace the malt grist.
- Specific cereals are used to provide desirable qualities in the beer, for example, flavour, colour, clarity, foam or physical stability.
- Wheat, rye and oats are used in many traditional beers in Europe. They provide distinctive flavours and can also contribute to foam stability.
- Starch-enriched fractions of maize and rice contain less nitrogen and fewer pro-oxidant enzymes (enzymes which favour oxidising reactions) than malted barley or malted wheat and are therefore often used to improve flavour stability in lighter flavoured beers, especially those where a longer shelf life is required.
- Cereals which do not contain gluten, such as maize, rice and sorghum, or buckwheat (which is technically not a cereal) may be used to make low gluten or gluten-free beers for people who suffer from coeliac disease and cannot tolerate gluten in their diets. Some of these cereals do not malt readily and are therefore often used as unmalted adjuncts.
- Use of unmalted cereals allows local cereals to be used and is important in areas where good quality malt is expensive or difficult to obtain. This includes much of Asia and Africa.
- The risk to food safety posed by unmalted cereals can be affected by the cereal type and the geographical area in which the cereal is grown.
- Different cereals vary in their vulnerability to specific moulds and therefore can contain different mycotoxins. For example, maize can contain fumonisins, which are rarely present in barley or wheat.
- Cereals grown in tropical or subtropical climates (for example, sorghum) are more likely to produce aflatoxins than cereals grown in temperate climates.
- Some cereals can preferentially accumulate certain heavy metals: arsenic is more likely to occur in rice, while wheat is known to accumulate cadmium.
- Cereals grown in areas of heavy industry can become contaminated with arsenic or heavy metals by atmospheric deposition. Such surface contamination is generally reduced by the washing/steeping stage of malting.
- In general, the risk posed by mycotoxins in unmalted cereals is similar to that for malted ones. However, the malting process can significantly reduce concentrations of some mycotoxins, particularly T-2 and HT-2 toxins.
- The risk of pesticide residues in grain is generally similar for unmalted and malted cereals, since residues of most pesticides are not significantly affected by the malting process. However, residues of insecticides used in grain storage can be significantly reduced during malting, so unmalted cereals could present a slightly higher risk.
- Bacterial contaminants present on unmalted cereals or on malt are destroyed during mashing and wort boiling.
- Some countries, especially in the EU, prescribe minimum amounts of malt which can be used in domestic production of beer. Such limits vary from 0% in the UK or Denmark to 100% for beer made according to the Reinheitsgebot in Germany.

# Part 3.
# Technical data

## 1. Why are unmalted cereals used in brewing?

Unmalted cereals are used in brewing to supplement or in some cases to partially or totally replace the malt grist. They are often referred to as brewing adjuncts. Unmalted cereals are used for specific purposes and to improve quality, either to provide certain characteristics in the beer which cannot readily be derived from malted barley or to avoid some of the problems associated with the use of malt *(Pierce, 1987).*
Some examples are listed below.

- **Whole unmalted wheat and barley:** These have a positive effect on foam and foam stability *(Lloyd, 1986; Morris & Hough, 1987; Depraetere et al, 2004).*
- **Maize and rice in the form of grits or flakes**: These products are generally prepared from endosperm-enriched cereal fractions and therefore contain a lower proportion of protein and lipid than the whole cereal. They offer a means of controlling the assimilable amino-nitrogen content of the wort, influencing the flavour of the final beer via the production of higher alcohols and esters and also by reducing the production of undesirable flavours such as diacetyl. Flavour stability can also be improved *(Maselis, 1993; Peppard et al, 1983; Hammond, 1986; Yano et al, 2008)*.
- **Reduction of oxidising potential:** Malted barley has both pro- and anti-oxidant activities *(Boivin, 2001: Kuroda et al, 2005).* Enzymes which favour oxidation (pro-oxidant) are especially associated with lightly kilned malts, such as those used for pale lagers, whereas antioxidant activities are developed at higher kilning temperatures and are therefore associated with speciality malts or roasted cereals. Use of unmalted cereals to replace part of the malt grist can therefore lower the concentration of malt-derived pro-oxidant enzymes, thus reducing the likelihood of stale, oxidised off-flavours in pale lagers..
- **Roasted cereals:** Coloured adjuncts prepared from unmalted cereals can have a major effect on finished beer colour and provide different flavour notes than those available from the use of special malts.
- **Oats and rye;** these have been used in traditional beers (for example, oatmeal stout in the UK, sahti in Finland) from northern European countries and impart characteristic flavour notes.
- **Non-traditional cereals:** Cereals other than the traditional barley and wheat are increasingly being used as adjuncts or as the main source of fermentable sugars in beer in order to produce beers with special health properties. Crops such as **buckwheat** (from the plant family Polygonaceae and not strictly speaking, a cereal, despite its name), **maize, quinoa** (from the family Chenopodium, and technically a pseudocereal since it is not a member of the grass family, Gramineae), **rice** and **sorghum** do not contain gluten and may be used to prepare beers which have no or reduced proportions of gluten, suitable for people who suffer from coeliac disease *(Guerra et al, 2009).* Some of these cereals can be difficult to malt so they are often used in the unmalted form.
- **Use of unmalted cereals** such as **rice** and **sorghum** has the added advantage in that it allows local cereals to be used in countries where the malting industry is not well developed, where local cereals do not easily produce an acceptable quality of malt**,** or where import of malt is very expensive or not permitted.

## 2. Unmalted cereal products available

Unmalted cereals may be used in a number of different forms, either as whole grains, or as processed products.
These include;

- **Grits:** These are coarse milling fractions produced from endosperm–enriched fractions and are lower in nitrogen and lipid than whole grains. They are uncooked.
- **Torrefied and micronized products:** Cleaned whole grains are treated with steam and water to pre-determined levels, held (tempering) for a precise period of time, then cooked to gelatinise the starch. Infra red heat is often used, which causes the endosperm to swell, giving a puffed appearance. The finished product is available as whole grains, flakes or ground into a meal. Wheat, barley, maize and oats are available in micronized form. Advantages include increased digestibility during mashing, improved clarity and better foam properties.
- **Flakes:** Either whole grains or grit fractions are steamed to gelatinise the starch, then rolled and dried. Flaked wheat is commonly used in wheat beers. Flaked barley is used to improve foam in stouts. Flaked maize and flaked rice may be used in some lagers to impart a drier, lighter flavour and colour.
- **Flours and starches:** Like grits but finer particle sizes, these are starch-rich milling fractions, often produced as by-products from the extraction of corn (maize) oil.

## 3. Implications of unmalted cereals for biological contaminants

Potential biological contaminants of cereals are very similar to those for malts, namely moulds and their by-products mycotoxins, seeds from other plants, bacteria and viruses, insects and mites, and contamination due to the presence of birds or animals such as rodents.

**3.1 Moulds and mycotoxins.** The potential for contamination with moulds and mycotoxins can be affected (positively or negatively) both by the cereal type and by the malting process itself.

**3.1.1 Effects of cereal type on mycotoxins and moulds.** Certain cereals are more susceptible than others to certain moulds and consequently are more likely to contain some mycotoxins. In addition, the prevalence of certain moulds, and consequently likely contamination with their associated mycotoxins is affected by climate, thus the source of the cereal is important. The mould *Aspergillus flavus,* which produces aflatoxins, requires warm, wet conditions, thus cereals grown in tropical or subtropical areas are much more likely to develop aflatoxins during growth than cereals grown in temperate climates.
**Barley:** Unmalted barley is more likely to contain the *Fusarium* mycotoxins T2 and HT-2 than malt or other unmalted cereals (except oats).
**Buckwheat:** Aflatoxins can occur in buckwheat; deoxynivalenol (DON) *(JECFA, 2001)* and ochratoxin A (OTA) *(Sugita-Konishi et al, 2006)* have also been reported. It may also contain ergot *(USDA, 2009).*
**Maize:** Unlike barley, maize supports the growth of the *Fusarium* moulds which produce fumonisins. Legal limits for fumonisins in maize are quite high (see Sections 5 and 6) since much maize is destined for processing into syrups, and this process removes fumonisins. However, in brewing,

there can be substantial carryover of fumonisins into the beer *(BRI, unpublished data: Scott et al, 1995; Pietri et al, 2010).* The Brewers of Europe's own survey of fumonisins in beers made with maize grits found that concentrations of total fumonisins ranged from 0.3 – 26 µg/litre (mean, 4.6) with the majority being below 10 µg/litre *(The Brewers of Europe, 2011).* Maize may also contain significant amounts of DON, zearalenone (ZEA) and, when sourced from warm temperate to subtropical climates such as Africa, parts of South America and the southern US, it may also contain aflatoxins. Those maize products used in brewing are endosperm-enriched fractions and may be lower in mycotoxins than whole grain, nevertheless brewers who use substantial quantities of maize should always test samples for mycotoxins, and should consider setting their own internal limits of acceptability for fumonisins.

**Oats:** Concentrations of T-2 and HT-2 mycotoxins can be significantly higher in unmalted oats than in other raw cereals or in malt. Although concentrations fall substantially when the husks are removed, this does not apply to the use of whole unmalted oats in brewing.

**Rice:** Mycotoxin contamination of rice is generally lower than that of other cereals *(Tanaka et al, 2007)*. However, aflatoxins, OTA, DON and fumonisins have been reported in rice. Rice products used in brewing are endosperm-enriched fractions and would be expected to be lower in mycotoxins than the whole grain. Rice adjuncts, therefore, present a lower risk for mycotoxin contamination than does barley malt.

**Rye:** Rye has not been studied as intensively as wheat, barley or maize. However, although DON can be detected in rye, concentrations are generally lower than in wheat *(Creppy, 2001)* and it appears to be genetically more resistant to DON accumulation than wheat *(Miedaner et al, 2008).* Rye is however more susceptible than many other cereals to infection by ergot. A study of ergot in rye flour in commercial mills in Denmark found that the average concentration of ergot alkaloids was 46µg/kg, with a maximum of 234µg/kg *(Storm et al, 2008).*

**Sorghum:** Sorghum is grown in tropical and sub-tropical regions, and is therefore susceptible to the formation of aflatoxins.

**Wheat:** Wheat tends to produce more DON and ZEA and less T-2 and HT-2 than barley does under comparable climatic conditions.

### 3.1.2 Effects of product type on mycotoxins

**Milling:** Studies suggest that mycotoxins in grain are redistributed during milling, with lower concentrations being found in grits and flour and higher concentrations in screenings, bran and germ fractions *(Schollenberger et al, 2008).* Maize flaking grits have also been observed to be generally significantly lower in mycotoxins than whole maize *(Scudamore & Patel, 2008).*

**Heat treatments:** The mycotoxins common on cereals (Fusarium mycotoxins, OTA, aflatoxin) are relatively stable to heat, and are not significantly affected by heat treatments in flaking, torrefaction or malt kilning.

### 3.1.3 Effects of malting process on mycotoxins and moulds.

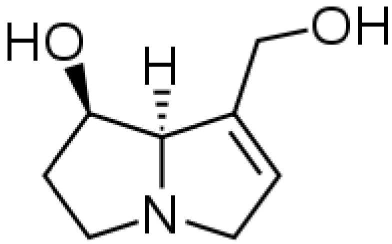
- Vegetative mould and mycotoxin concentrations are often higher in small grains, broken pieces of grains and in the dust from the husk and outer layers of the grain *(Magan & Olsen, 2004)*. These fractions are removed during screening, and since malted grain is effectively screened twice (once before and once after malting), removal is more effective for malted grain than for unmalted grain.

- Water soluble toxins, in particular **T-2 and HT-2** fusarium toxins, are reduced substantially during steeping, thus the raw grain can contain significantly higher concentrations of these toxins than malted barley normally does *(Baxter & Boivin, 2007).*
- In theory, the humid conditions typical of germination and the earlier stages of kilning are conducive to mould growth and mycotoxin formation *(Baxter & Muller, 2006; Wilhelmson et al, 2009).* In practice, however, average concentrations of the main fusarium toxins **deoxynivalenol** (DON), **nivalenol** (NIV) and **zearalenone** (ZEA) and of **ochratoxin A** (OTA) are broadly similar in unmalted and malted barley *(Gareis, 1999; Vandemeulebroucke et al, 2003*: *Baxter, 2006: Baxter et al, 2009).* However, the behaviour of individual batches can vary widely, depending upon the season and the prevalence of viable mould inoculum. Both increases and decreases of mycotoxins during malting have been reported *(Sypecka, et al, 2003).*
- The source of the cereal must also be considered. Cereals destined for malting must be carefully dried and stored to conserve viability. It is possible that cereals from other sources may be less carefully stored, thus increasing the potential for growth of *Penicillium verrucosum* and development of OTA during storage.

Overall, therefore, unmalted cereals are just as likely, if not more likely, to contain *Fusarium t*oxins and OTA as barley malt.

### 3.2 Seeds from other plants

Seeds from some plant species can contain natural toxicants such as alkaloids and glucosides. These are often resistant to processing, thus it is important that such seeds are removed before the grain is milled and used in brewing. Those most likely to occur in cereals are the seeds of plant species *Heliotropium* and *Crotalaria* (which are common as weeds in cereal crops in the US and Africa) and *Senecio* (for example, ragwort and groundsel, both common weeds in Western Europe). These plants produce pyrrolizidine alkaloids, which can accumulate in the seeds, and are liver toxins. The risk of contamination with these seeds is likely to be slightly higher in unmalted cereals of European origin because of the reduced amount of screening compared with malt, and significantly higher in unmalted cereals of non-European origin because of the wider range of climatic conditions.



Structural formula of retronecine, a pyrrolizidine alkaloid found in *Senecio vulgaris* (common groundsel).

Legal limits for the amount of such seeds which may be present are set in some Codex standards for cereals and in EU legislation for animal feedingstuffs (see Sections 5 and 6).

### 3.3 Bacteria and viruses

All cereals may be contaminated with bacteria and/or viruses from human and animal sources, both in the field (birds, foxes, rodents) and during storage. A wide range of bacteria, including coliforms have frequently been reported on raw grain *(Haikara et al, 1977; O'Sullivan et al, 1999).* Levels are highest immediately after harvesting and decline somewhat during storage *(Haikara et al, 1977)*. For malting barley and malt, contamination during storage can be largely controlled by good hygienic practices in stores *(Euromalt, 2005).* There is some reduction in cell numbers during kilning, but coliforms are relatively stable to dry heat, and can survive malt kilning *(Haikara et al, 1977; O'Sullivan et al, 1999).*Thus neither unmalted or malted cereals can be regarded as sterile commodities, although the risk of bacterial contamination would be expected to be slightly lower for malted or roasted cereals because of the heat treatment. Cereals in general present a lower risk than fresh produce such as salads because they are usually subjected to less intense irrigation and handling than fresh produce. Raw cereals have not been associated with contamination with enterohemorrhagic coliforms such as *E. coli* 0157.

Any coliforms and other pathogens on malt or unmalted cereals are destroyed during mashing and boiling, thus do not give rise to contamination in the beer. In one published study, no coliforms could be detected after 50 minutes of mashing at 63°C *(O'Sullivan et al, 1999).*

## 4. Chemical implications of use of unmalted cereals in brewing

There are a number of chemical contaminants which can occur in cereals.
**Arsenic:** All cereals can contain trace levels of arsenic, generally absorbed from the soil or sometimes from atmospheric deposition in areas of heavy industry. However, different plant types may take up arsenic from the soil at different rates and **rice** is known to accumulate arsenic more than other cereals (see **Table 1**). The steeping stage of malting will reduce arsenic contamination from atmospheric deposition, thus unmalted cereals sourced from areas close to heavy industry present a greater risk for this type of contamination that does malt. However, the malting process has little effect on systemic concentrations of arsenic (that is, those taken up by the roots from arsenic in the soil).

**Table 1. Total arsenic in EU cereals *(data source: EFSA, 2009).***

| **Cereal** | **% samples < LOD** | **Mean As (LB-UB)* µg/kg** |
|---|---|---|
| Cereal grains excluding rice | 77 | 14.7 – 40.5 |
| Rice grains | 9.8 | 136 - 142 |
| Cereal products excluding rice | 60 | 10.7 – 29.7 |
| Rice products | 28 | 142 - 166 |

**LB = lower bound. This is the value assuming that all analyses below the limit of detection (or determination) are equal to zero. It may underestimate actual concentrations.*
*UB = upper bound. This is the value assuming that all analyses below the limit of detection (or determination0 are equal to that limit. It is likely to overestimate actual concentrations.*

Chronic ingestion of inorganic arsenic is associated with neurotoxicity and cancer of the lung, skin and urinary tract *(EFSA, 2009).* The EFSA Panel considered that the Provisional Tolerable Weekly Intake (PTWI) of 15µg/kg body weight set by JECFA was no longer appropriate, and instead identified a range of values of 0.3 – 8 µg/kg body weight/day for the $BMDL_{01}$ (the Benchmark Dose associated with an extra 1% risk of lung cancer, the most sensitive end-point) should be used instead when estimating risk. The Panel further noted that estimated dietary intake in Europe was already within this range and recommended that dietary exposure to inorganic arsenic should be reduced.

**Cyanogenic glucosides and cyanide:** Over 200 species of plants (including cereals, particularly sorghum and maize) can produce cyanogenic glucosides which, under certain conditions, can produce hydrogen cyanide. However, most of these do not cause problems under normal conditions of harvesting and use. Most plant-induced cyanide poisoning is associated with the consumption of poorly prepared cassava in tropical countries *(Knight & Walter, 2002).*

**Dioxins and dioxin-like PCBs:** These are environmental toxins which can occur at trace levels in most foods. They are not very soluble in water and tend to concentrate in fatty tissues. Concentrations in plant materials (excluding vegetable oils themselves) are therefore naturally low compared with animal tissues. There is little data comparing dioxin and dioxin-like PCBs in different cereals but it is unlikely that concentrations would differ significantly in those used as brewing adjuncts. With oil-rich cereals such as rice and maize, the fractions normally used in brewing are derived from those fractions remaining after the oil has been extracted, or are from the starch-rich, low-fat endosperm milling fractions. Concentrations are unlikely to be affected by malting. Unmalted cereals are thus likely to present a similar, or in some cases slightly lower, risk with regard to dioxins and dioxin-like PCBs as malt. In the EU legal limits for dioxins and dioxin-like PCBs are only set for high fat foodstuffs.

**Heat generated toxins (acrylamide, furan, 3-MCPD):** These are produced by high temperature processing, as in the production of crystal, coloured and roast malts and roasted cereals. They are not produced at normal grain drying temperatures. Thus unmalted cereals other than heat treated products would not be expected to contain heat-generated toxins.

Concentrations in roasted products are governed by the temperature and moisture conditions during roasting in exactly the same way as for malted products. Formation of **chloropropanols** such as 3-MCPD requires quite high temperatures, and 3-MCPD has not been detected in cereal products such as torrefied cereals, which are only subjected to very brief heat treatments. Concentrations in roasted unmalted cereals are similar to those in malted cereals of the same colour.
**Furan and acrylamide** can be formed at lower temperatures and could potentially be found in flaked and torrefied products. No data is available for furan, but acrylamide has been detected in flaked and torrefied cereals at concentrations slightly higher than those normally found in lager malt. Concentrations of acrylamide and furan in roast barley are similar to those in roast malt of the same colour. There is some evidence that different cereals can give rise to different concentrations of acrylamide and this may be related to different concentrations of the amino acid asparagine (a precursor of acrylamide) in different types of cereals. This may be the

reason for the higher concentration of acrylamide in roasted rye.
Data is given in **Table 2**.

**Table 2. Heat generated toxins in unmalted adjuncts**
***(data sources: see footnotes)***

| Adjunct type | Acrylamide µg/kg | Furan µg/kg | 3-MCPD µg/kg |
|---|---|---|---|
| **Flaked wheat** | 39[1] | Not tested | Not tested |
| **Flaked barley** | 35[1] | Not tested | Not tested |
| **Flaked maize** | 40[1] | Not tested | Not tested |
| **Torrefied barley** | 51[1] | Not tested | <10 (LOQ) |
| **Torrefied wheat** | 115-132[1] | Not tested | |
| **Roast barley** | 15 – 185[1] | 2855-4330[3] | Up to 500[2] |
| **Roast rye** | 737[1] | 3030[3] | Not tested |
| **Concentrations in malts for comparison** | | | |
| **Lager malt** | 3 -10[1] | <50[3] | <10 (LOQ)[2] |
| **Roasted malts (black, chocolate)** | 12 – 210[1] | 2304 – 3581[3] | Up to 500[2] |

LOQ = Limit of quantification
[1] *Hamlet et al, 2005.*
[2] *Baxter et al, 2005.*
[3]*BRI, unpublished data. Samples were analysed by headspace GC/MS using solid phase micro-extraction and a deuterated internal standard.. The limit of quantification was 5µg/kg.*

*For more information see The Brewers of Europe TISs on furan, acrylamide and 3-MCPD.*

**Heavy metals:** As with arsenic, heavy metals deposited on the grain surface from atmospheric contamination in areas of heavy industry can be reduced to some extent during steeping, so unmalted cereals from such areas present a greater risk that malted ones. However, the malting process has little effect on systemic metal concentrations, so unmalted cereals in general present the same risk as their malted counterparts.
Different cereal types, however, may accumulate metals to a greater extent than barley and thus present a greater risk than barley malt. **Rice and Wheat** have a greater tendency to accumulate cadmium than has barley and other cereals (**Table 3**). This is reflected in the higher limits set for cadmium in these cereals in the EU (see legislation section 5). The highest concentrations of cadmium are found in bran and germ fractions, but these are not normally used as adjuncts in brewing
Cadmium is primarily a kidney toxin and can also cause demineralization of bone. It is classed as a Group 1 carcinogen by IARC. EFSA have established a TWI of 2.5µg/kg body weight for cadmium and estimated that current dietary intakes in Europe are close to or slightly above this level *(EFSA, 2009).*

**Table 3. Total cadmium in EU cereals *(data source: EFSA, 2009b).***

| Cereal | % samples < LOD | Mean Cd µg/kg |
|---|---|---|

| | | |
|---|---|---|
| Cereals and cereal products excluding wheat and rice | 84 | 17.1 |
| Wheat grains and flour | 88 | 30 |
| Wheat products | 83 | 13.7 |
| Rice | 88 | 25.3 |

**NDMA and other N-nitroso compounds:** NDMA is a recognised carcinogen and many other N-nitroso compounds are also carcinogenic. Since these compounds are formed during the kilning stage of malting, they would not be expected to be present in unmalted cereal products such as maize grits, flaked maize, barley, wheat and rice, micronized wheat and barley or torrefied barley. No NDMA has been detected in any such samples analysed.

**Pesticides:** cereal grains can contain residues of pesticides which have been applied either to the plant during growth in the field or to the harvested grain to protect it against insects and mites during storage. The concentration of such residues which may be present in marketed grain is controlled by legislation in the EU and in most other countries. However the actual concentrations permitted (MRLs) can vary significantly between cereals and between countries (see Legislation sections). Imported cereals can therefore present the greatest risk of non-compliance. Concentrations of storage insecticides are generally reduced to some extent during malting, since these chemicals are associated with the outer layers of the grain and are therefore more easily removed by screening and steeping: they are also broken down to some extent during kilning *(Armitage et al, 2005).* Concentrations of field-applied pesticides are likely to be similar in malted and unmalted grain.

**Polycyclic aromatic hydrocarbons (PAHs):** PAHs are a large group of 200-300 hydrocarbons containing more than one aromatic (benzene) ring fused together either in a straight chain or an angular arrangement. About 20 occur most frequently and these are the focus of most attention. They are ubiquitous environmental contaminants, being formed mainly as a result of combustion of organic material from both natural (volcanoes, forest fires) and anthropomorphic sources (burning of fuel, vehicles, combustion of waste etc). Certain PAHs (particularly phenanthrene, fluoranthene and pyrene) are typically found in many plants, including cereals and hops. It has been suggested that drying of crops using direct driers could cause contamination with PAHs and a report prepared for the 37$^{th}$ session of Codex recommended that direct driers should no longer be used for food crops *(Codex, 2005).* Subsequently, the Codex Committee on Contaminants in foods has produced a Code of Practice for reduction of PAH contamination which recommends that direct drying be avoided for cereal and oilseeds *(Codex, 2009).* However, studies commissioned by the HGCA (the cereals and oilseeds division of the UK's Agriculture and Horticulture Development Board) and carried out at Campden BRI found little evidence that direct drying has any significant effect on PAHs in malting barley under normal conditions. *(Baxter et al, 2010)*. Concentrations of PAHs in speciality malts and roast cereals were within the range found in pale malts. This suggests that the risk presented by PAHs in unmalted cereals is similar to that presented by malts.

*For more information on PAHs see The Brewers of Europe TIS on PAHs.*

## 5. Relevant EU legislation

**Contaminants in Cereals:** Regulation 1881/2006 and its amendments set limits for contaminants (other than pesticides) in foodstuffs in the EU *(EC, 2006).* Details are given in tables 4a and 4b below.

### Table 4a. Limits for chemical contaminants in cereals in the EU *(EC, 2006).*

| Contaminant | Matrix | Maximum |
|---|---|---|
| **Heavy metals (mg/kg)** | | |
| **Lead** | Cereals | 0.2 |
| **Cadmium*** | Cereals, excluding bran, germ, wheat and rice | 0.1 |
| | Bran, germ, wheat and rice | 0.2 |
| **PAHs (µg/kg)** | | |
| **Benz(a)pyrene** | Processed cereal-based foods | 1.0 |

* *these are under review following the publication of the EFSA Opinion.*

### Table 4b. Limits for mycotoxins in cereals in the EU *(EC, 2006).*

| Contaminant | Matrix | Maximum µg/kg |
|---|---|---|
| **Mycotoxins** | | |
| **Aflatoxins** | All cereals and all products derived from cereals, including processed cereal products, with the exception of foodstuffs otherwise specified. | Aflatoxin B1 : 2<br>Total aflatox. : 4 |
| | Maize and rice to be subjected to sorting or other physical treatment before human consumption or use as an ingredient in foodstuffs | Aflatoxin B1 : 5<br>Total aflatox : 10 |
| **Ochratoxin** | Unprocessed cereals | 5 |
| | Products derived from unprocessed cereals *(includes malted cereals)* | 3 |

### Table 4b. continued : Fusarium mycotoxins

| Mycotoxin | Matrix | Max. Conc. µg/kg |
|---|---|---|
| | Unprocessed cereals, other than durum wheat, oats and maize | 1250 |
| | Unprocessed durum wheat and oats | 1750 |

| | | |
|---|---|---|
| **Deoxynivalenol** | Unprocessed maize except unprocessed maize intended to be processed by wet milling | 1750 |
| | Cereals for direct human consumption, cereal flour, bran and germ as end product marketed for direct human consumption, except for foodstuffs listed separately | 750 |
| | Milling fractions of maize with particle size > 500 micron (CN code 1103 13 or 1103 20 40) : other maize milling products with particle size > 500 micron not for direct human consumption (CN code 1904 10 10). | 750 |
| | Milling fractions of maize with particle size ≤ 500 micron (CN code 1102 20) and other maize milling products with particle size ≤ 500 micron not used for direct human consumption ( CN code 1904 10 10). | 1250 |
| **Fumonisins (sum of B1 and B2)** | Unprocessed maize with the exception of unprocessed maize intended to be processed by wet milling | 4000 |
| | Maize intended for direct human consumption, maize-based foods for direct human consumption, with the exception of foodstuffs otherwise specified | 1000 |
| | Milling fractions of maize with particle size > 500 micron (CN codes 1103 13 or 1103 20 40) and other maize milling products with particle size > 500 micron not used for direct human consumption (CN code 1904 10 10). | 1400 |
| | Milling fractions of maize with particle size ≤ 500 micron falling within CN code 1102 20 and other maize milling products with particle size ≤ 500 micron not for direct human consumption (CN code1904 10 10). | 2000 |
| **Sum of T2 and HT-2 toxin** | Not yet set | |
| **Zearalenone** | Unprocessed cereals other than maize | 100 |
| | Unprocessed maize, unless intended for wet milling | 350 |
| | Cereals intended for direct human consumption, except for otherwise specified, cereal flour, bran and germ as end product marketed for direct human consumption, | 75 |
| | Maize intended for direct human consumption, maize-based snacks and maize-based breakfast cereals | 100 |
| | Milling fractions of maize with particle size > 500 micron (CN codes 1103 13 or 1103 20 40) and other maize milling products with particle size > 500 micron not used for direct human consumption (CN code 1904 10 10). | 200 |
| | Milling fractions of maize with particle size ≤ 500 micron (CN code 1102 20) and other maize milling products with particle size ≤ 500 micron not used for direct human consumption ( CN code 1904 10 10). | 300 |

**Pesticides:** Statutory residue limits (MRLs) are imposed on the agricultural crop to which the pesticide is applied, not to finished foods. The setting of pesticide MRLs in the EU is controlled by Regulation 396/2005 *(EC, 2005)*. The annexes listing individual MRLs are established by Regulation 149/2008 *(EC, 2008)* and numerous following Regulations which amend Regulation 396/2005. The current MRLs are listed in a searchable database maintained by the EC.

In the EU, an MRL is set for each chemical / crop combination. Thus many of the MRLs set for a crop relate to pesticides which are not used on that crop, and are generally set at the limit of quantification for that pesticide. This is a different approach to that of the WHO and of many other countries (including the USA). In these countries MRLs are only set for pesticides which are used on that crop. It should be emphasised that MRLs are set according to the amount which must be applied to give adequate control of the relevant pest or disease (provided that this is safe according to a toxicological review). They are generally well below the safety threshold. Thus MRLs for the same crop/chemical combination can vary widely between different countries

MRLs have not yet been set for all the pesticides authorised in the EU, but once this process is complete, the default limit of 0.01 mg/kg will apply to any active ingredient not included in Regulation 396/2005.

**Gluten:** Any food or beverage (including alcoholic beverages) made from or with a gluten containing cereal must be labelled "contains X", where X is the name of the cereal *(EC, 2011).* The EU has adopted the revised Codex standard for the composition of "low gluten" and "Gluten free" foods. See Section 6 for details.

**Compositional legislation for beer:** There is no EU-wide legislation which prescribes the amount of malt which must be used to make beer. Accordingly, national legislation prevails, and this is very varied. Some countries (for example, Denmark, the UK) do not set any minimum malt content: others set a minimum, ranging usually from 40 – 60%. In Germany, bottom fermented beers made according to the Reinheitsgebot must be made from 100% malt. The Brewers of Europe maintains a list of legal compositional beer definitions for the EU countries and other major beer producing countries world wide. A copy of this list is included as a separate document in the Annex to this TIS.
New regulations are currently being introduced in Russia which may results in a minimum malt content being set for beers.

**Animal feed:** Legislation on undesirable materials in animal feed sets limits for mycotoxins and chemical contaminants in plants used for animal feed *(EC, 2002)*. These limits are generally set higher than those allowed in cereals for human food. This legislation also sets an overall limit of 3000 mg/kg for weed seeds containing alkaloids, glucosides and other toxic substances, as well as individual limits for specific plant species including *Crotalaria, Ambrosia, Ricinus* (castor oil) and *Fagus* (beech).

## 6. Legislation on unmalted cereals in non-EU countries

### CODEX Standards:

**Gluten;** The WHO Codex Alimentarius standard for gluten free products was revised in 2008 *(Codex, 2008).* The revised standard distinguishes between

1. "gluten free" products, which are not made from gluten containing cereals and which must not contain more than 20 mg/kg gluten in the food as sold, and

2. "very low gluten" foods specially processed to reduce gluten, which may be made from gluten-containing cereals and which may contain > 20 mg/kg but < 100 mg//kg gluten in the food as sold. The name by which these products may be described on the label will be decided at national level.

**Contaminants in cereals: Codex Standard 193-1995** sets upper limits for a number of contaminants in some cereals in international trade and also includes sampling recommendations. These often form the basis for EU limits and are given in **Table 5** *(Codex, 1995)*.

Codex has also published a Code of Practice for avoiding the presence of mycotoxins in cereals *(Codex, 2003)*.

### Table 5. Codex limits for contaminants in cereals

| Contaminant | Matrix | Limit |
|---|---|---|
| **Aflatoxin** | No limits set for cereals | |
| **Ochratoxin A** | Raw wheat<br>Barley<br>Rye | 5 µg/kg |
| **Cadmium** | Cereals (except wheat, rice, | 0.1 mg/kg |
| | Polished rice | 0.4 mg/kg |
| | Wheat | 0.2 mg/kg |
| **Lead** | Cereals (except for buckwheat, cañihua, quinoa) | 0.2 mg/kg |
| **3-MCPD** | No limits set for cereals | |

There are also a number of Codex standards for individual cereals (see **Table 6**). These set limits for such quality criteria as moisture, extraneous organic matter (such as foreign seeds) and extraneous inorganic matter (such as stones, sand, dust etc). Heavy metals should not be present in concentrations which are hazardous to health, but numerical limits are not set. These individual standards do not set limits for pesticides or mycotoxins, which are covered by separate standards. Some of these standards specifically exempt materials used as brewing adjuncts.

**Table 6. Codex Standards for cereals and relevant cereal products**

| Standard | Title | Scope | Quantitative Quality Criteria |
|---|---|---|---|
| 152-1985<br><br>Amended 1995 | Wheat flour | Wheat flour for direct human consumption. Does **NOT** apply to flour for brewing adjuncts | Moisture<br>Flour treatment agents<br>Hazardous microorganisms<br>Protein<br>Fat acidity<br>Particle size |
| 153-1985<br><br>Amended 1995 | Whole maize | Whole maize for human consumption | Moisture<br>Toxic seeds<br>Other organic matter<br>Inorganic matter |
| 154-1985<br><br>Amended 1995 | Whole maize meal | Whole maize (corn) meal for direct human consumption. Does **NOT** apply to brewing adjuncts | Moisture<br>Hazardous microorganisms<br>Protein<br>Fat acidity<br>Particle size<br>Other maize |
| 155-1985<br><br>Amended 1995 | Degermed maize meal and grits | For direct human consumption. Does **NOT** apply to meal or grits for brewing adjuncts. | Moisture<br>Hazardous microorganisms<br>Protein<br>Fat acidity<br>Particle size |
| 170-1989<br>Amended 1995 | Pearl millet flour | For direct human consumption. Does not apply to grits. | Moisture<br>Hazardous microorganisms<br>Protein,Fat<br>May contain permitted food additives |
| 172-89<br><br>Amended 1995 | Sorghum grains | For direct human consumption. | Moisture<br>Organic & inorganic foreign matter<br>Toxic seeds<br>Tannins<br>Hazardous microorganisms<br>Protein,Fat,Fibre |
| 178-1991<br><br>Amended 1995 | Durum wheat flour | Durum wheat semolina and flour for direct consumption or use in other foods | Moisture<br>Hazardous microorganisms<br>Protein<br>Particle size.<br>May contain added nutrients |
| 198-1995 | Rice | Husked or milled rice for direct consumption. Does not apply to other rice products. | Moisture<br>Organic & inorganic extraneous matter<br>Hazardous microorganisms<br>Dead insects<br>Broken grains<br>May contain added nutrients. |

**Table 6 cont. Codex Standards for cereals and relevant cereal products**

| Standard | Title | Scope | Quantitative Quality Criteria |
|---|---|---|---|
| 199-1995 | Wheat and durum wheat | Wheat and durum wheat grains intended for processing | Moisture<br>Ergot, Toxic seeds<br>Organic & inorganic extraneous matter<br>Hazardous microorganisms<br>Dead insects<br>Shrunken, broken or damaged kernels<br>Insect bored kernels<br>None-wheat cereal grains |
| 201-1995 | Oats | Oats intended for processing for human consumption. Does not apply to hulless oats | Moisture<br>Ergot, Toxic seeds<br>Organic & inorganic extraneous matter<br>Dead insects<br>Hazardous microorganisms<br>Shrunken, broken or damaged kernels<br>Insect bored kernels<br>None-oats cereal grains<br>Wild oats |

## Other contaminant legislation for cereals: Mycotoxins.

**Codex Standard CRC-MRL** sets maximum residue limits for certain pesticide/crop combinations, including cereals. These are relatively limited in number and, since they must accommodate agricultural practice world-wide, are frequently higher than EU MRLs. Current Codex MRLs are contained in a searchable on-line database at
http://www.codexalimentarius.net/pestres/data/index.html

Many countries set maximum limits for aflatoxins in cereals, although these can be variable. A few set limits for other mycotoxins (DON, ochratoxin A, ergot, T-2 toxin). Table 7 gives some limits as listed by the FAO Worldwide mycotoxins legislation database. Note; this was last updated in 2003 *(FAO, 2003).*

**Table 7. Some maximum limits for mycotoxins in cereals worldwide.**
***(Data source, FAO, 2003)***

| Country | Matrix | Mycotoxin | Limit (µg/kg) |
|---|---|---|---|
| **Australia/NZ** | Cereal grains | ergot | 500,000 Weight of ergot kernels/commodity weight |
| **Brazil** | All food | Aflatoxins B1 & G1 | 30 |
| **Canada** | Soft wheat flour | DON | 1200 |
| **Canada** | Wheat, oats, barley, rye, buckwheat, Canada triticale, | ergot | Various limits expressed as wt% |
| **China** | Maize & maize products | Aflatoxin B1 | 20 |
| | Rice | Aflatoxin B1 | 10 |
| | Other grains | Aflatoxin B1 | 5 |
| | Wheat, maize & their flours | DON | 1000 |
| **India** | All food | Total aflatoxin | 30 |
| **Indonesia** | Maize | Zearalenone | ND |
| **Japan** | All food | Aflatoxin B1 | 10 |
| | Wheat & wheat products | Ochratoxin | 1100 |
| **Korea** | Grains | Aflatoxin B1 | 10 |
| **Malaysia** | All foods | Total aflatoxin | 35 |
| **Mexico** | Cereals & products | Total aflatoxin | 20 |
| **Mercosur** | Maize | Total aflatoxins | 20 |
| **Russia** | Cereals & cereal products | Aflatoxin B1 | 5 |
| | Wheat | DON | 700 |
| | Barley | DON | 1000 |
| | Barley | T2 | 100 |
| | Wheat, barley, maize, corn | Zearalenone | 1000 |
| **South Africa** | All foods | Aflatoxin B1 | 5 |
| | | Total aflatoxins | 10 |
| **Switzerland** | All foods | Aflatoxin B1 | 2 |
| | | Total aflatoxins | 4 |
| | | Ochratoxin | 5 |
| | Cereal grains | DON | 1000 |
| **Tanzania** | All foods | Aflatoxin B1 | 5 |
| | | Total aflatoxins | 10 |
| **Turkey** | Cereals & flours | Aflatoxin B1 | 2 |
| | | Total aflatoxins | 4 |
| | Raw grain | Ochratoxin | 5 |
| | Foodstuffs from grain | | 3 |
| **Ukraine** | Grains | Aflatoxin B1 | 5 |
| | Soft wheat & flour | DON | 500 |
| | Hard wheat & flour | | 1000 |
| | Grains | T-2 toxin | 100 |

## Other contaminant legislation for cereals: Pesticides

Most countries set limits for pesticide residues (MRLs) which may be present on raw cereals (and other crops) as a result of application in the field or during storage. As already mentioned, these can vary quite widely between different countries, with most countries except the EU only setting MRLs for pesticides used on crops grown in their country. Countries such as

Japan which import a significant proportion of food crops take into account limits set in other countries.
Many countries operate searchable on-line databases giving current MRLs for each crop. Some examples are given below.

**Australia;** MRLs are included in the Food Standards Code, Standard 1.4.2 and apply only to Australia *(FSANZ, 2011)*.
**Canada:** MRLs are set under the Pest Control Products Act *(Health Canada, 2011).*
**Japan:** Pesticide MRLs are set by the Ministry of Health, Labour and Welfare. The Japanese Food Chemical Research Foundation operates a searchable database *(JFCRF, 2011).*
**New Zealand:** MRLs are set by the New Zealand Food Safety Authority and are given in a searchable database *(NZFSA, 2011).*
**Turkey:** pesticide MRLs are being harmonised to those in the EU.
**Ukraine:** The Ministry of Ecology and Natural Resources (MENR) publishes an annual catalogue of pesticides and agricultural chemicals allowed for use in Ukraine. This includes MRLs for different crops. However, this does not appear to be available on-line.
**US:** Pesticide crop tolerances are set by the Environmental Protection Agency (EPA) and are published in the Federal Register. A searchable database for international MRLs is operated by the USDA *(USDA, 2011).*

### Compositional legislation for beer outside the EU.

Most beer-producing countries outside the EU do not lay down minimum limits for the proportion of malt which must be used in beer. However a few do: limits range from 10% malt in South Korea to 67% in Japan. Legislation on composition of beer is currently being drafted in Russia but was not finalised at the time of writing.

The details for some important beer producing countries in Europe, Asia and America are contained in The Brewers of Europe list of compositional beer definitions already referred to (see Annex).

## 7. Good practices for the brewing sector

- Ensure that all unmalted cereals used are included in any raw material due diligence analytical programmes.
- Ensure that analytes sought are appropriate for the cereal type and its geographical origin.
- If possible, source unusual cereals from approved, audited suppliers. If this is not possible, additional testing may be necessary.
- If non-standard adjuncts are used, for example for a niche or seasonal product, check that they are included within HACCP programmes.

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# Part 4. Frequently asked questions

**Q. 1 What is the difference between malted and unmalted cereals?**

A.1 The cereals normally used to make malt are barley and wheat. In order to make malt, the raw grain is first cleaned and screened to remove impurities such as stones, straw and weed seeds, then soaked in water for up to 2 days. The grain is drained and then held in controlled conditions of temperature and humidity to allow the grains to germinate (that is, they start to grow and produce roots). After about 4-5 days of germination, the grains are dried in a kiln. The amount of heat applied varies according to the type of malt being made. Pale malts, for the production of light coloured lagers, are not kilned as much as the darker malts used to brew ales and dark lagers or stouts.

**Q.2 What is the advantage of malting grain?**

A.2 The germination process encourages the grain to release natural enzymes which start to break down its internal structure. This means that starch can be more easily released during brewing and broken down into sugar, which is then fermented into alcohol. Kilning, as well as halting the germination process, also produces colour and flavour in the malt, which then provides colour and flavour in the beer.

**Q.3 So why are unmalted cereals used in brewing?**

A.3 There are many reasons why unmalted cereals are used in brewing. Only certain cereals produce good malt – barley is the best for making malt, although wheat malt is also important for some European beers. Using unmalted cereals means that a much wider range of cereals can be utilised. Some of these have particular characteristics that can improve the quality of the beer, or produce distinctive styles of beer. Unmalted wheat can improve the foam on beer: maize and rice are used to produce beers with drier flavours and improved flavour stability: oats and rye provide distinctive flavours and are often used in traditional dark beers and stouts.

Unmalted cereals are generally, but not always, less expensive than malt, so replacing some of the malt with unmalted cereal can help to keep costs – and prices – down.

**Q.4 How much unmalted grain is used to make a particular beer?**

A.4 It can vary very widely, depending upon the style of beer and where it is made. Many beers derive most of their fermentable sugars from malt, with unmalted cereals being used to supplement the malt, either to provide particular characteristics, or to improve efficiency of production. Some lighter flavoured lagers will use greater proportions of unmalted cereals. Lagers may also be produced exclusively from unmalted cereals using external enzymes. Beers produced according to the German Reinheitsgebot may use only malted barley.

**Q.5 Are unmalted cereals used in other countries?**

A.5 Yes, unmalted cereals are widely used outside Europe. In some countries barley and wheat do not grow very readily. Traditionally brewers would use whatever cereals were available locally, so oats and rye are more popular in northern Europe, whilst rice and maize are widely used in Asia, Africa, the southern US and southern Europe. Nowadays, traditional products from other countries are becoming increasingly popular worldwide, so a wider range of cereals may be used in any one country.

**Q.6 I have coeliac disease and I have heard that some beers can be produced which do not contain gluten?**

A.6 Yes, gluten-free or reduced gluten beers are available and can be made in a number of different ways. Some are made from cereals such as rice, maize and sorghum which do not contain the gluten proteins. Others are made from cereal-like grains, such as buckwheat or quinoa, which also do not contain gluten. Now it is even possible to make a gluten-free beer using normal malted barley or wheat, but using special enzymes to break down the gluten so that none remains in the beer. The World Health Organisation has developed standards for the maximum amount of gluten which may be present in foods and beverages which claim to be low in or free from gluten, and the EU follows these standards.

**Q.7 How can I tell which of those methods has been used?**

A.7 Under current EU legislation, any beer made with a gluten-containing cereal MUST state the name of that cereal on the label. So a gluten-free beer made from barley or wheat (whether or not it has been malted) will still have to state "Contains barley" or "Contains wheat" on the label. A beer which is made entirely from gluten-free cereals does not have to state the name of the cereal on the label, although some do so voluntarily.

**Q.8 Is the use of unmalted rather than malted cereals harmful in any way?**

A.8 Cereals are a healthy and safe foodstuff, whether or not they have been malted. Beers made with unmalted cereals are produced under exactly the same strictly controlled and hygienic conditions as those made entirely from malt and are just as safe to drink.