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Gluten and cereals containing gluten: occurrence and health relevance

Gluten is a natural component of many types of cereal. It consists of specific protein components that are prevalent in wheat varieties (including spelt, emmer and einkorn), rye, barley and, in small amounts, oats. Its distinctive property is that it makes dough elastic and ensures that bread becomes light and airy. This is why gluten is so important in the baking process. Many foods made from cereals, such as bread, pasta and pastries, contain gluten. It may also be present in other processed foods such as sauces, chips or sausages, for example as an additive to improve consistency. For most people, gluten poses no problem. It has been consumed in cereal-based foods for thousands of years – without any adverse health effects. However, it can have adverse effects in cases of certain allergies or hypersensitivities, such as wheat allergy and coeliac disease.

In the chronic condition known as coeliac disease, the immune system reacts to gluten. Even small amounts can damage the small intestine and cause nutrient deficiencies. Those affected must therefore strictly avoid gluten for the rest of their lives. Wheat allergy is also triggered by certain protein components in wheat play, which can cause an allergic reaction in those affected after consuming wheat.

Avoiding gluten is not recommended unless medically necessary. On the contrary: anyone who avoids gluten-containing foods without a medical reason often restricts their diet unnecessarily and puts their health at risk. Cereals, particularly wholemeal products, provide important nutrients such as dietary fibre, vitamins and minerals, and are an essential part of a healthy diet.

What is gluten?

The term 'gluten' generally refers to a specific protein component found in certain types of cereals. 'Gluten' is the umbrella term for the cereal storage proteins (also known as prolamins and glutelins), which, accounting for 70 to 80 per cent, make up the main component of cereal protein and are found in the starchy endosperm of the grain (Scherf and Köhler, 2016) . In wheat, they are called gliadins and glutenins.

Traditionally, the term 'gluten' is used in connection with the baking properties of wheat flour. 'Gluten' comes from Latin and means 'glue'. The gliadins and glutenins contained in wheat form the well-known 'gluten protein' or 'wheat gluten' and give the flour a high water-absorption capacity, as well as imparting gas retention, viscosity and elasticity to the dough (Scherf and Köhler, 2016) .

In addition to its role in baking, gluten has various other properties. For example, it acts as an emulsifier, stabiliser and carrier of flavouring substances, and has gelling properties. It is therefore also widely used as an additive in the food industry and can be found in many processed foods (DZG, 2022) .

In the context of food regulations, 'gluten' is defined as the protein component found in wheat, rye, barley and oats, which some people cannot tolerate and which is insoluble in water and a specific salt solution (Regulation (EU) No 828/2014) .

In addition to gluten (prolamins and glutelins), cereals also contain other protein components known as albumins and globulins. These include, for example, β -amylase, α -amylase-trypsin inhibitors (ATIs) and lipid transfer proteins (Scherf and Köhler, 2016) .

Which cereals contain gluten

All commonly consumed cereals (wheat, rye, barley, oats, maize, rice and millet), which botanically belong to the grass family (see **Figure 1**), contain storage proteins from the prolamin and glutelin fractions and thus, strictly speaking, gluten. In wheat, these storage proteins are known as gliadins and glutenins; in rye they are called secalins; in barley, hordeins; in oats, avenins; in maize, zeins; in rice, oryzins; and in millet, kafirins (Day, 2013; Scherf and Köhler, 2016; Wieser et al., 2020) .

Depending on their degree of relatedness, these storage proteins exhibit minor to significant differences in their structural composition compared to wheat gluten. Whilst wheat, rye and barley are closely related and are botanically classified as members of the wheat grasses, oats are classified as members of the oat grasses (Rimbach et al., 2025) . Overall, the storage proteins – particularly in rye and barley, but also in oats due to their closer relationship to wheat – are similar and are therefore collectively referred to as 'gluten', although oats contain only small amounts of these proteins (Daly et al., 2025) . By contrast, the corresponding storage proteins in other cereal species such as maize, rice and millet, which belong to the grass family, differ significantly in their structural composition due to their more distant evolutionary relationship. They are therefore not classified as 'gluten' – particularly in the context of food regulations (Biesiekierski, 2017; Cebolla et al., 2018) .

In accordance with the Food Information Regulation applicable throughout Europe (Regulation (EU) No 1169/2011) , the term 'cereals containing gluten' covers the following cereals: wheat (all wheat (*Triticum*) species), rye, barley and oats (including their hybrids and derivatives). Wheat species include common wheat (generally referred to as 'wheat'), durum wheat, Khorasan wheat, spelt (including 'Grünkern': spelt harvested whilst still green), emmer and einkorn.

Plant species that look and are used in a similar way to grains but do not belong to the grass family are referred to as pseudo-cereals. They belong to the amaranth or knotweed families. Examples of pseudocereals include amaranth, quinoa and buckwheat. Pseudocereal species do not contain gluten (BZL, 2025) .

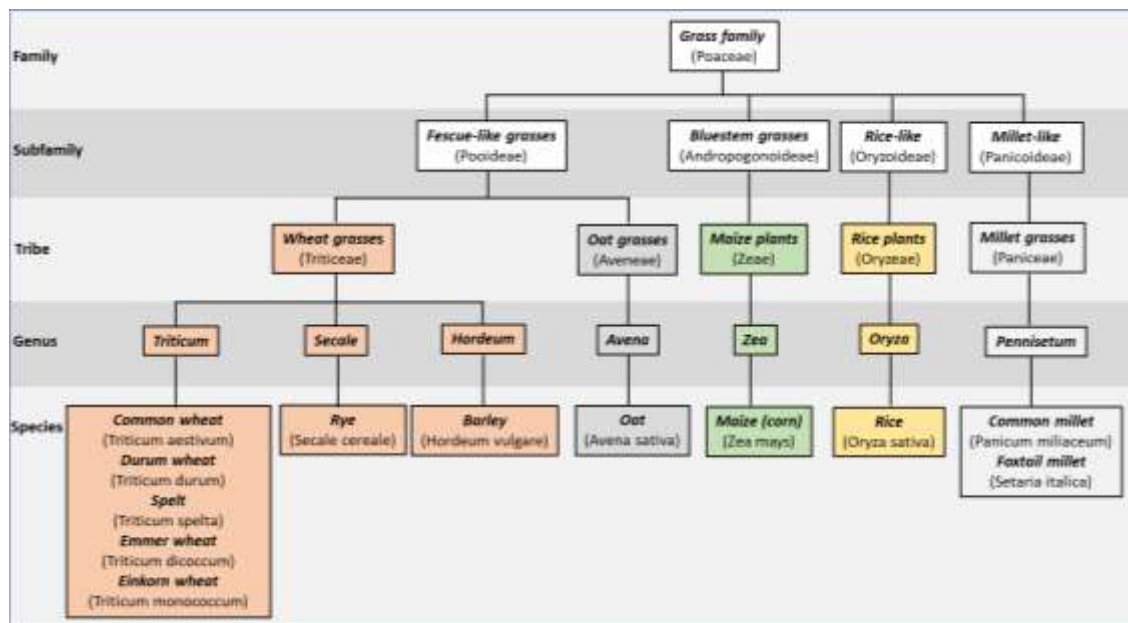


Figure 1 Systematic classification of grasses (modified from (Breuer, 2014; Rimbach et al., 2025) .

Which foods contain gluten

Cereals containing gluten include wheat, rye, barley and oats, as well as their hybrids and derivatives (Regulation (EU) No 1169/2011) . A wide range of conventional cereal-based foods are made from cereals containing gluten: these include, for example, cereal products such as flour, semolina, couscous, flakes and bulgur, as well as bread, baked goods, pastries and various pasta products such as noodles and pizza dough, or even seitan and malt-based drinks. Furthermore, gluten is also present in various other processed foods such as sausages, soups, sauces and sweets as a processing aid, for example as a binding agent (DZG, 2022; Luque et al., 2024) .

Which foods do not contain gluten?

Unprocessed staple foods such as vegetables, fruit, meat, milk, eggs, fish, potatoes, pulses (such as soya, peas, lentils or beans), tree nuts (such as hazelnuts or cashews) or oilseeds (such as linseed or sesame) do not contain any gluten naturally . However, processed foods made from them may contain gluten if they are produced using ingredients that contain gluten. This is indicated in the list of ingredients (Felber et al., 2022; Luque et al., 2024) .

Foods that do not contain any gluten naturally also include gluten-free cereals (such as rice, millet and maize) and pseudo-cereals (such as amaranth, buckwheat and quinoa). These are often used as substitutes for gluten-containing cereals and products made from them (Felber et al., 2022; Luque et al., 2024) .

However, with processed foods, in addition to the possibility that gluten may be present as a separate ingredient – particularly in those made from cereals or pseudo-cereals – there is always a risk of contamination with gluten during the harvest, production or storage process (Felber et al., 2022; Luque et al., 2024) .

People who need to avoid gluten due to coeliac disease are therefore advised to choose products labelled as 'gluten-free'.

How gluten and gluten-containing cereals are labelled on food packaging

In accordance with the EU Food Information Regulation (Regulation (EU) No 1169/2011), foods that most commonly cause allergies or hypersensitivities – including cereals containing gluten, namely wheat, rye, barley, oats or hybrid strains thereof – must be mandatorily labelled on the packaging of pre-packaged foods. The list of ingredients sets out the ingredients that are intentionally added to the food in accordance with the recipe. The list of ingredients also indicates whether, for example, wheat or products derived from it are contained in the product as an ingredient. For greater clarity, this must also be visually highlighted in the list of ingredients (e.g. in bold, underlined or italics). With regard to the use of different types of wheat, the generic term 'wheat' must be clearly stated in the list of ingredients, e.g. spelt (wheat) (European Commission, 2017). As it is the specific cereal containing gluten (e.g. wheat or rye) – and not the term 'gluten' – that must be labelled in the list of ingredients, it is important for people who need to avoid gluten due to coeliac disease to be aware of which cereals contain gluten.

Ingredients derived from gluten-containing cereals, but whose names do not clearly indicate this, must also be labelled accordingly, for example 'modified starch (wheat)'. Similarly, gluten-containing fillers for flavourings or additives must also be labelled on the packaging.

Certain ingredients produced from gluten-containing cereals, such as glucose syrup, dextrose (glucose, grape sugar), maltodextrin (a mixture of carbohydrates) and alcoholic distillates, are exempt from the labelling requirement, as they no longer contain gluten or allergy-triggering proteins due to the high degree of processing they undergo. Nevertheless, when using these ingredients, some manufacturers list the gluten-containing raw material in brackets in the list of ingredients (Felber et al., 2022).

Since 2014, there has also been a legal labelling requirement for allergens, including gluten-containing cereals, for so-called loose goods (= unpackaged goods from bakeries, butchers or restaurants) (LMIDV, 2017).

What the labelling 'gluten-free' or 'very low gluten content' on food products means

The terms 'gluten-free' and 'very low gluten content' on food packaging and their use are regulated by EU law (Regulation (EU) No 828/2014). The regulations were introduced to enable people with coeliac disease to choose products safely.

Removing gluten from cereals containing gluten involves considerable technical and financial effort, which is why it is difficult to produce completely gluten-free foods using such cereals. Consequently, many foods on the market that have been specially processed to reduce the gluten content of one or more gluten-containing ingredients may contain small residual amounts of gluten.

Under EU Implementing Regulation (EU) No 828/2014, the term 'gluten-free' may only be used on food packaging if the food in question contains no more than 20 milligrams (mg) of gluten per kilogram (kg). This also applies to oats labelled as 'gluten-free'. A food labelled as 'gluten-free' may therefore contain very small amounts of gluten. For most people with coeliac disease, however, these are considered safe. The specified maximum permitted concentration is intended to limit daily gluten intake to less than 10 mg. This means that up

to 500 g of products with 'gluten-free' labelling can be consumed per day without exceeding the amount of 10 mg of gluten per day, which is still considered safe (FAO/WHO, 2025) .

Some manufacturers use the 'gluten-free' symbol – a crossed-out ear of wheat – to indicate compliance with the maximum limit of 20 mg/kg of gluten. This symbol is recognised throughout Europe and is awarded in accordance with the standard set by *the Association of European Coeliac Societies* (AOECS). If manufacturers wish to display this symbol on their products, they must apply to the relevant national coeliac society for a quality assessment, known as an audit. In Germany, this is the German Coeliac Society (Deutsche Zöliakie Gesellschaft, DZG). If the products meet the AOECS quality standard – which includes, amongst other things, gluten analysis – manufacturers can obtain a licence to use the 'gluten-free' symbol on food packaging.

The AOECS-licensed symbol of the crossed-out ear of grain looks as follows and also includes a code identifying the country ("Land"), the manufacturer ("Hersteller") and the product ("Produkt"):



Foods with labelling that shows a crossed-out ear of grain designed by the manufacturer themselves – which may in some cases bear a strong resemblance to the licensed symbol – are not, from a legal perspective, required to be gluten-free. The DZG therefore advises people with coeliac disease to look out for the 'gluten-free' claim and the licensed crossed-out ear of grain symbol when shopping.



Symbols not licensed by the AOECS

The statement 'very low gluten content' may only be used if a food product consisting of, or containing, one or more ingredients made from wheat, rye, barley, oats or crosses of these cereals – which have been specially processed to reduce their gluten content – has a gluten content of no more than 100 mg/kg of food. However, for people suffering from coeliac disease, medical societies as well as the German and European Coeliac Societies (DZG and AOECS) recommend exclusively products with 'gluten-free' labelling, as these offer greater safety (Felber et al., 2022) .

Products labelled 'gluten-free' – not necessarily free from wheat

Foods with 'gluten-free' labelling are not necessarily free from other wheat constituents. Whilst gluten-free products are suitable for people with coeliac disease, they are not necessarily suitable for people with a wheat allergy, as they may, for example, contain other wheat proteins or even very small amounts of gluten (up to 20 mg/kg), which can trigger symptoms in some people with a wheat allergy.

The list of ingredients helps people with a wheat allergy to determine whether wheat is present, even in gluten-free products.

What ‘May contain traces of wheat’ means

Even when produced with the utmost care, food – particularly processed products – may, under certain circumstances, become contaminated with substances known to trigger allergies (such as gluten-containing cereals). This can occur during production, transport or the presentation of the product. Unlike the legal requirements for labelling where gluten-containing cereals, such as wheat, are deliberately used as an ingredient in a food product, there is currently no legal regulation governing the unintentional presence of allergens in food and, consequently, no mandatory labelling. Consequently, manufacturers often include voluntary warnings on products (for example: ‘may contain traces of ...’), partly to guard against potential liability claims. For consumers, however, it is not clear whether this is done purely as a precaution for product liability reasons or on the basis of the manufacturer’s allergen management practices. Due to the lack of a legal requirements and the voluntary nature of such labelling, it is therefore currently impossible to draw any conclusions – either from the absence or the presence of a warning – as to whether an allergen, such as wheat, has inadvertently entered the product.

Within the framework of the Codex Alimentarius Committee – a joint Committee of the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO) of the United Nations, which develops international standards for food – work has been underway for several years on regulations for the labelling of unintentional presence of allergens (FAO/WHO, 2023) . In 2026, the Codex Committee on Food Labelling (CCFL) drew up guidelines on the use of precautionary allergen labelling, taking into account the reports from the FAO/WHO expert consultations (FAO/WHO, 2026).

Foods labelled ‘gluten-free’ with the statement ‘may contain traces of wheat’ and what this means

Under current legislation, foods labelled as ‘gluten-free’ may contain no more than 20 milligrams (mg) of gluten per kilogram. A warning regarding unintentional allergen contamination (‘traces warning’), however, is not yet regulated by law. If products labelled as ‘gluten-free’ also carry a warning about unintentional presence from gluten-containing cereals such as wheat, this means that wheat may be processed at the manufacturer’s same facility. Consequently, even products labelled as ‘gluten-free’ may contain components of gluten-containing cereals such as wheat. However, the manufacturer must guarantee compliance with the legal gluten limit of 20 mg/kg and ensure that products labelled accordingly are therefore also suitable for people with coeliac disease.

The guidelines on the use of precautionary allergen labelling, drawn up in 2026 by the Codex Committee on Food Labelling (CCFL), recommend that, where precautionary allergen labelling (‘traces’ statement) is required for cereals containing gluten (wheat, barley and rye), the term ‘gluten-free’ shall not be used (FAO/WHO, 2026).

For certain medical conditions, the consumption of gluten or wheat poses a health risk

A gluten- or wheat-free diet is medically necessary for only a few medical conditions. These include medically diagnosed coeliac disease and wheat allergy, each of which affects around

one per cent of people in Europe. For these individuals, the consumption of gluten or wheat poses a health risk. For this reason, there are specific labelling requirements on food products for cereals containing gluten, such as wheat.

What is coeliac disease?

Coeliac disease is a chronic, systemic, immune-mediated intestinal disorder triggered in genetically predisposed individuals by the intake of gluten (Al-Toma et al., 2019; Felber et al., 2022) . In Germany, around 1 per cent of the population is affected (Laass et al., 2015; Makharia et al., 2022) . However, it is thought that the condition often goes undiagnosed. The condition frequently develops in early childhood, although in principle it can manifest at any age (Werkstetter and Koletzko, 2020) .

In people with coeliac disease, gluten components stimulate the immune system, on the one hand, to produce gluten-specific T-cells, which play a role in inflammatory reactions in the intestinal tissue, and, on the other hand, via B-cell stimulation, to produce immunoglobulin A antibodies that target certain endogenous proteins in the intestine, known as 'coeliac-specific antibodies' (Cabanillas, 2020) . As a result of these processes, continued consumption of gluten in affected individuals leads to inflammation and damage to the small intestine mucosa (atrophy of the intestinal villi), which is associated with an increased risk of a range of health effects. In addition to chronic intestinal damage, gluten can also trigger acute symptoms in people with coeliac disease who otherwise follow a gluten-free diet, thereby causing impairment of their quality of life (FAO/WHO, 2025) .

The occurrence of symptoms in coeliac disease

The occurrence of symptoms in coeliac disease can vary considerably from person to person, both in terms of their severity and in terms of the number and type of symptoms. Possible symptoms include, amongst others, chronic diarrhoea, constipation, vomiting, nausea, bloating and (persistent) abdominal pain. In addition, the occurrence of a wide range of other, more non-specific symptoms is possible that do not affect the digestive tract, such as chronic fatigue, unexplained weight loss and headaches (AOECS, 2026) .

Some people affected show no clinical symptoms (initially) despite damage to the small intestine's mucosa. If undiagnosed and untreated, coeliac disease can have a range of health consequences: changes to and damage of the intestinal mucosa can disrupt the intake of important nutrients, which, as the disease progresses, can lead to symptoms of nutrient deficiency. Examples of this include iron deficiency with a significant reduction in red blood cells (iron-deficiency anaemia), osteoporosis or developmental delays in children, which may manifest, for example, as poor weight gain, growth disorders and delayed puberty. Long-term complications can also affect other organ systems, such as the reproductive system (e.g. infertility, pregnancy complications) or the nervous system (e.g. nerve damage, impaired motor coordination) (AOECS, 2026; Felber et al., 2022) .

Undiagnosed and untreated coeliac disease can increase the risk of certain cancers and cardiovascular diseases. Coeliac disease is often associated with other autoimmune conditions such as type 1 diabetes mellitus, autoimmune inflammatory liver disease and thyroid disorders (AOECS, 2026; Felber et al., 2022) .

How coeliac disease can be diagnosed

People who suspect they may have coeliac disease should seek clarification from a specialist. According to the current medical guidelines on coeliac disease, the diagnosis is based on three main pillars: a medical history, a blood test for the detection of specific antibodies, and, if necessary, a small bowel biopsy. It is strongly advised against adopting a gluten-free diet on one's own initiative, without prior medical assessment and a confirmed medical diagnosis, as a regular and sufficient intake of gluten via the diet is crucial for a valid diagnosis (AOECS, 2026; Felber et al., 2022) .

Which cereals are harmful in coeliac disease?

In people with coeliac disease, gluten is responsible for damage to the small intestine tissue (Fraser and Ciclitira, 2001) , particularly the gluten fractions (prolamines) found in wheat, rye and barley. These proteins contain specific patterns that are recognised by the immune system of those affected (Sollid et al., 2020) .

Due to oats' more distant relationship to wheat, the frequency and structure of prolamins and coeliac disease-relevant recognition patterns in oats differ more significantly from the more closely related prolamins found in wheat, rye and barley (Daly et al., 2025) . Avenin from oats is therefore immunologically ineffective or less effective in many coeliac patients and consequently causes no symptoms or, more rarely, only mild symptoms (Comino et al., 2015; Hardy et al., 2015; La Vieille et al., 2016; Lionetti et al., 2018; Tanner et al., 2019) . In very rare cases, however, avenin in oats can also trigger symptoms in people with coeliac disease (Arentz-Hansen et al., 2004; Hardy et al., 2015) .

Maize, rice and millet, despite containing storage proteins from the gluten fractions, are safe for people with coeliac disease and recommended as part of a gluten-free diet due to their much more distant relationship to wheat (Felber et al., 2022; Luque et al., 2024) . Pseudo-cereals such as amaranth, quinoa and buckwheat contain no gluten and are therefore well tolerated by coeliac patients (Felber et al., 2022; Luque et al., 2024) .

Oats (and oat products) are well tolerated by most people with coeliac disease

According to the current state of research, oats and foods made from them are well tolerated by most (but not all) people with coeliac disease (Arentz-Hansen et al., 2004; Hardy et al., 2015) .

However, conventionally grown oats may be contaminated with wheat, rye and barley, as these cereals are often grown side by side and processed in the same facilities (Claßen, 2018) . Commonly available oats or oat products are therefore not suitable for people with coeliac disease. However, according to the current coeliac disease guidelines, oats and oat products labelled as 'gluten-free' may be consumed by people with coeliac disease provided they do not experience any symptoms (Felber et al., 2022) . Introduction to these products should take place under specific conditions and under medical supervision. Furthermore, close medical monitoring is recommended, as in rare cases the avenin in oats can cause symptoms in coeliac patients (Arentz-Hansen et al., 2004; Felber et al., 2022; Hardy et al., 2015) .

According to EU regulations, oats labelled as 'gluten-free' or 'very low in gluten' must be produced, prepared and/or processed in such a way as to rule out any contamination by wheat, barley, rye or crosses of these cereals. The gluten content of these oats must not exceed 20 mg per kg (Regulation (EU) No 828/2014) . Oats and oat products labelled as

‘gluten-free’ may also be labelled with the crossed-out ear of grain symbol, supplemented where appropriate by the word ‘OATS’ (DZG, 2023; Felber et al., 2022) .

As oats contain plenty of dietary fibre, protein, minerals, B vitamins and polyunsaturated fatty acids, oats labelled as ‘gluten-free’ can, provided they are well tolerated, be a valuable addition to a gluten-free diet and broaden the range of food choices available to people with coeliac disease (Felber et al., 2022; Luque et al., 2024) .

How to replace the symptoms of coeliac disease

There is no curative treatment for coeliac disease. Those affected must therefore follow a strict gluten-free diet for life in order to avoid symptoms and prevent long-term complications. This requires strict avoidance of gluten in the diet (Felber et al., 2022; Husby et al., 2020; Mearin et al., 2022; Werkstetter and Koletzko, 2020) . A gluten-free diet consists of foods that do not naturally contain any gluten, such as unprocessed vegetables, fruit, dairy products, eggs, meat, fish, certain cereals and pulses, as well as products labelled ‘gluten-free’, e.g. as substitutes for cereal products (Melini and Melini, 2019) . For people with coeliac disease, any exposure to gluten is problematic. Causes of unintentional exposure include undeclared gluten-containing ingredients, as well as unintentional gluten contamination of packaged and unpackaged foods or during food preparation. For those affected, individual dietary management by a qualified dietitian or nutritionist is important to ensure a safe yet balanced diet with adequate nutrient intake (Al-Toma et al., 2019) . In cases of proven micronutrient deficiency (particularly iron, vitamin B12, folic acid, vitamin D and calcium) or clinical symptoms of deficiency (e.g. iron-deficiency anaemia), appropriate nutritional supplementation should be provided (Felber et al., 2022) . When selecting supplements, care must also be taken to choose products labelled as ‘gluten-free’.

Therapeutic measures and any follow-up checks should always be carried out under medical supervision and on medical advice. Diagnosis and dietary changes should therefore always be supported by a doctor and a dietitian or nutritionist (Al-Toma et al., 2019) .

The (daily) gluten intake at which no adverse health effects are expected

People with coeliac disease may be able to tolerate small amounts of gluten, although this varies from person to person. Overall, however, the evidence regarding a safe level of gluten intake for people with coeliac disease is limited (Luque et al., 2024; Spector Cohen et al., 2020) . Studies, primarily involving adult coeliac patients, show that the daily tolerable amount of gluten varies greatly – both from patient to patient and from study to study. Based on the limited evidence available, no health effects are expected for the vast majority of patients with an intake of up to 10 mg of gluten per day (Akobeng and Thomas, 2008; Catassi and Chirido, 2025; Rostami-Nejad et al., 2023) . Whether even small amounts of gluten (<10 mg) could have long-term health effects in a subgroup of particularly sensitive coeliac patients has not been sufficiently investigated.

The legally stipulated limit value of 20 milligrams (mg) per kilogram (ppm/parts per million) of food, which applies in the EU for the labelling of ‘gluten-free’ foods, aims to limit daily gluten intake to a maximum of 10 mg. This would correspond to the consumption of up to 500 g of food labelled as ‘gluten-free’ with a maximum gluten content of 20 ppm. Accordingly, the current guidelines on coeliac disease also recommend a strict ‘gluten-free’ diet with the aim of keeping gluten intake below 10 mg per day (Felber et al., 2022) .

Overall, further research is needed – including on the health effects of occasional gluten intake, the health risks of consuming very small amounts of gluten (<10 mg/day) over a long period, and a safe level of gluten intake for children with coeliac disease (Catassi et al., 2025; Luque et al., 2024) .

The timing of gluten introduction during complementary feeding does not appear to influence the risk of coeliac disease

According to current scientific evidence, the age or timing of introducing gluten as part of complementary feeding does not appear to influence the risk of coeliac disease in infants. Introducing gluten early, from the age of 17 weeks, does not reduce the subsequent risk of coeliac disease. Delaying the introduction of gluten-containing foods in genetically predisposed children appears to delay the onset of coeliac disease, but not to prevent it (Bührer et al., 2016; Abou-Dakn et al., 2025).

In accordance with the current recommendations of national medical societies on infant nutrition and coeliac disease prevention, gluten-containing foods may be introduced from the start of weaning – from the beginning of the fifth month of life at the earliest – initially in small quantities (e.g. one spoonful of cereal porridge), with the amount being gradually increased (Abou-Dakn et al., 2025; Felber et al., 2022; Koletzko et al., 2016) . These recommendations apply to all children, regardless of whether or not they have an increased genetic risk of developing coeliac disease.

Symptoms that may occur with a wheat allergy

In the case of a wheat allergy, those affected experience allergic reactions following contact with wheat. The immune system reacts to proteins in wheat, with the reaction usually being mediated by immunoglobulin E (IgE) antibodies. Various proteins in wheat may be responsible for a wheat allergy – in addition to gluten (gliadins and glutenins), these include albumins and globulins (Fowler and Kaufman, 2021; Jiang et al., 2025; Srisuwatchari et al., 2025) . The prevalence of IgE-mediated wheat allergy is estimated to be less than 1 per cent worldwide and in Germany (Kalb et al., 2026; Liu et al., 2023; Neyer et al., 2025; Nwaru et al., 2014) .

‘Classic’ primary wheat allergy, in which allergic symptoms occur shortly after consuming wheat, is particularly common in infancy and early childhood (Ricci et al., 2019) . The majority of affected children develop natural oral tolerance by the time they reach school age or adolescence; many young children even develop it just a few years after diagnosis (Czaja-Bulsa and Bulsa, 2014, 2017; Kalb et al., 2026; Keet et al., 2009; Kotaniemi-Syrjänen et al., 2010) .

Even shortly after consuming small amounts of wheat, a wide range of allergic reactions can occur, which may affect the skin, the digestive tract, the respiratory tract and/or the cardiovascular system, such as hives, itching, severe abdominal pain or shortness of breath (Dölle-Bierke et al., 2023; Neyer et al., 2025) .

People with a wheat allergy often show sensitisation to other gluten-containing cereals such as rye or barley, which is most likely due to IgE cross reactivity. The extent to which allergic reactions may occur following the consumption of rye or barley in individuals with a wheat allergy has not yet been thoroughly investigated and, in cases of doubt, must be assessed on

an individual basis (Du et al., 2022; Faihs et al., 2024; Jones et al., 1995; Kennard et al., 2018; Srisuwatchari et al., 2020; Takei et al., 2022; Yanagida et al., 2022) .

Wheat can also trigger non-IgE-mediated allergic reactions. These include, for example, eosinophilic oesophagitis or food protein-induced enterocolitis syndrome (FPIES), in which gastrointestinal symptoms may occur with delayed onset (Felber et al., 2022) .

The extent to which other gluten-containing cereals (rye, barley and oats) are significant triggers of IgE-mediated allergies remains unclear; the available data on this are limited (FAO/WHO, 2022; Fowler and Kaufman, 2021) .

How a wheat allergy is diagnosed

People who suspect that they or their child may have an allergy to wheat or another gluten-containing cereal should seek a medical advice from a specialist. It is important to note that the detection of sensitisation to wheat (wheat-specific IgE antibodies) via a blood or skin test (skin prick test) alone is not conclusive – in other words, a positive blood or skin test does not automatically mean that a wheat allergy is present. A diagnosis also requires a thorough medical history and, where necessary, a medically supervised oral provocation test with wheat (Felber et al., 2022; Worm et al., 2024) . Similarly, in cases of doubt, individual tolerance to other gluten-containing cereals can only be determined by means of an oral provocation test (Cox et al., 2021) .

How to avoid allergic reactions in cases of wheat allergy

To avoid allergic reactions in cases of classic wheat allergy, once a diagnosis has been confirmed by a doctor, wheat (durum and soft wheat, Khorasan wheat/Kamut) as well as related wheat varieties and wheat hybrids (triticale and tritoredum) must be avoided in the diet (Felber et al., 2022; Worm et al., 2021) . Related wheat varieties also include so-called ancient grains or primitive varieties of wheat such as spelt (including green spelt), einkorn and emmer. Due to their close relationship and the high similarity of their allergens, these wheat varieties can also trigger allergic reactions (Waßmann and Schäfer, 2014) ; for example, the allergens in spelt are almost identical to those in wheat (Sievers et al., 2020) . Wheat (protein) is also frequently present in processed products, which is often only apparent to those affected by carefully reading the ingredients list. For an individualised approach to dietary changes, consultation with a qualified dietitian or nutritionist with expertise in allergy is important (Al-Toma et al., 2019) . Those affected are advised on safe food choices, learn to identify wheat and wheat-based products in food, are informed about possible alternatives, and learn how to ensure an adequate intake of essential nutrients.

In many children, wheat allergy resolves by the time they reach school age or adolescence (Czaja-Bulsa and Bulsa, 2014, 2017; Keet et al., 2009; Kotaniemi-Syrjänen et al., 2010) . Therefore, children should undergo (repeat) wheat challenge testing at regular intervals following the initial diagnosis to check whether the allergy is still present. If the test is negative, wheat should be reintroduced in the child's diet so that they do not have to go without wheat and its important nutrients for an unnecessarily long time, and also to maintain tolerance (Worm et al., 2021) .

What is an augmentation factor- or exercise-triggered wheat allergy?

A specific form of IgE-mediated wheat allergy is wheat-dependent *exercise-induced anaphylaxis* (WDEIA) or *wheat allergy dependent on augmentation factors* (WALDA), whose occurrence is particularly common in adults. In this condition, the allergic reactions triggered by wheat only occur in combination with specific, temporally related co-factors (augmentation factors), such as, in particular, physical exertion, but also the intake of non-steroidal anti-inflammatory drugs or the consumption of alcohol. This can lead to mild allergic reactions, such as skin symptoms, or even severe anaphylactic reactions (Faihs et al., 2023a; Faihs et al., 2023b) . When not combined with the individual co-factor, most affected individuals tolerate wheat without any problems. Omega-5 gliadin (Tri a 19) is considered the main trigger of WDEIA/WALDA (Fowler and Kaufman, 2021) .

Wheat is one of the most common triggers of food-induced anaphylaxis in Germany and Europe (Dölle-Bierke et al., 2023; Kraft et al., 2021; Worm et al., 2024) .

What is ‘baker’s asthma’?

Also IgE-mediated, but not classified as a food allergy, is what is known as ‘baker’s rhinitis’ or ‘baker’s asthma’. In this form of wheat allergy, inhaling wheat proteins from flour dust – for example, whilst working with wheat flour – leads to allergic rhinitis or asthma. Consuming bread and other products containing wheat, on the other hand, is generally well tolerated. As the name suggests, this form of occupational, respiratory wheat allergy has a high prevalence among bakers (Cianferoni, 2016) .

The clinical picture referred to as ‘non-coeliac gluten/wheat sensitivity’ (NCGWS)

‘Non-coeliac gluten/wheat sensitivity’ (NCGWS) describes a clinical presentation in which those affected report gastrointestinal symptoms such as abdominal pain, bloating or reflux, as well as other symptoms such as fatigue or headaches, following the consumption of foods containing gluten or wheat (Felber et al., 2022; Layer et al., 2021; Manza et al., 2025) . The symptoms often resemble those of irritable bowel syndrome. However, unlike coeliac disease and wheat allergy, there are no clear diagnostic criteria, including specific diagnostic markers and scientifically proven triggers (Felber et al., 2022; Worm et al., 2021) . Little is yet known about the underlying mechanisms either. It is thought that the innate immune response, with potentially non-IgE-mediated reactions to wheat – particularly in individuals with irritable bowel syndrome – as well as an impairment of the intestinal barrier, play a role (Felber et al., 2022; Manza et al., 2025) .

In addition to gluten, other wheat components such as FODMAPs (fermentable carbohydrates, such as fructans) and other wheat allergens, for example amylase-trypsin inhibitors, are now among the triggers under discussion (Al-Toma et al., 2019; Felber et al., 2022; Layer et al., 2021; Reese et al., 2018) . However, studies with individuals suspected of having NCGWS have so far failed to confirm a clear trigger.

Furthermore, placebo and nocebo effects appear to play a role in the presentation of symptoms. For instance, several placebo-controlled studies have observed that the expectations of those affected regarding the food to be consumed can influence the occurrence or absence of the reported symptoms (de Graaf et al., 2024; Manza et al., 2025; Moleski et al., 2021; Zimmermann et al., 2022) .

NCGWS is therefore not a clearly defined clinical condition. In accordance with the guidelines of medical societies, it is only considered once coeliac disease (on a gluten-containing diet) and a wheat allergy have been definitively ruled out (Felber et al., 2022; Layer et al., 2021) .

An unfounded, long-term avoidance of foods containing gluten is not recommended, as this can have adverse health effects. Diagnosis and any subsequent dietary changes should therefore always be supervised by a doctor and a dietitian or nutritionist. People who suspect they experience symptoms after consuming gluten or wheat should seek clarification from a specialist, particularly as a self-initiated gluten-free diet could mask a possible case of coeliac disease.

According to current research, ancient wheat varieties are no better tolerated than 'modern' wheat

It is frequently claimed that 'older' types of wheat, particularly spelt, are in some cases better tolerated than 'more modern' types such as common and durum wheat. Possible causes cited include changes in the composition of wheat protein – in particular, an alleged lower gluten content – as well as modern breeding methods. However, the scientific evidence to date does not support this assumption.

The so-called 'ancient forms of wheat', which include spelt (including 'Grünkern', i.e. spelt harvested whilst still green), emmer and einkorn, belong, like soft and durum wheat, to the genus *Triticum* (see Figure 1). They are therefore different types of wheat. Spelt is also a subspecies of common wheat. Consequently, the proteins of the different wheat species—particularly those of spelt and common wheat—are very similar. However, differences in protein composition are influenced not only by species and variety, but also, in particular, by environmental factors (Afzal et al., 2021; Afzal et al., 2023) .

Studies from Germany show that 'more modern' wheat varieties (particularly common wheat) have, on average, lower concentrations of protein, gluten and gliadin – a gluten component relevant to coeliac disease – than 'older' wheat varieties such as spelt, einkorn and emmer (Brouns et al., 2022; Geisslitz et al., 2019) . A decline in protein and gliadin content has also been observed within common wheat breeding over the last 100 years, whilst the gluten content has remained constant overall (Pronin et al., 2020) . Regardless of the type of wheat, the gluten content of baked goods may be increased through the technologically driven addition of gluten, for example to achieve a greater volume during baking.

In addition to gluten, all types of wheat – both common wheat and its ancient varieties (spelt, emmer and einkorn) – contain various other potentially allergenic proteins, such as so-called amylase/trypsin inhibitors (ATI) (Sievers et al., 2020) . Comparable ATI concentrations have been found in both modern and traditional common wheat varieties. It therefore appears that modern breeding practices have no significant influence on ATI concentrations (El Hassouni et al., 2021; Geisslitz et al., 2023; Jahn et al., 2025) . At the protein level, there is evidence to suggest that einkorn appears to have lower ATI concentrations and, overall, lower proportions of potentially allergenic proteins than common wheat, spelt and emmer (Afzal et al., 2023; Geisslitz et al., 2020) . However, it is unclear whether this leads to better tolerability of einkorn compared with other wheat varieties, as there are no relevant human studies.

Laboratory studies (*in vitro*) have so far found no evidence that proteins from ‘ancient’ wheat species and varieties have a lower immunoreactive potential than those from ‘modern’ wheat species and varieties (Dieterich et al., 2022) . To date, there are no conclusive human studies demonstrating that spelt has a lower allergenic potential than common wheat (the BfR, 2020; Faihs et al., 2024; Felber et al., 2022; Sievers et al., 2020) . Even in people without a wheat allergy, human studies have failed to demonstrate any subjectively better tolerability of ancient wheat varieties such as spelt compared with ‘modern’ wheat (Zimmermann 2022).

Health risks of a gluten-free diet

A gluten-free diet may pose health risks, particularly in terms of an unbalanced nutrient intake. In general, restrictive exclusion diets carry a risk of an unbalanced diet and, consequently, an inadequate nutrient intake. Avoiding gluten or products made from gluten-containing cereals severely limits food choices, which can lead to changes in nutrient intake, particularly if suitable alternatives are not taken into account (DGE, 2016) . In contrast, for those with medically diagnosed coeliac disease or a wheat allergy, a strictly gluten-free or wheat-free diet is medically necessary; for these individuals, the benefits of a gluten-free or wheat-free diet are vast compared to the potential health risks. In such cases, however, nutritional support from a dietitian or nutritionist experienced in the relevant clinical condition is essential to ensure a safe diet that also provides a balanced intake of fibre and nutrients (Al-Toma et al., 2019; Felber et al., 2022; Worm et al., 2021) . A gluten-free diet without a medical necessity primarily poses health risks and requires extensive knowledge of food in order to compensate for potential nutrient deficiencies through a carefully planned diet (DGE, 2016) .

Further information on coeliac disease and allergies to gluten-containing cereals (some in German only)

Updated S2k guideline on coeliac disease from the German Society for Gastroenterology, Digestive and Metabolic Diseases (DGVS):

<https://register.awmf.org/de/leitlinien/detail/021-021>

Update of the S2k guideline on the management of IgE-mediated food allergies:

<https://pmc.ncbi.nlm.nih.gov/articles/PMC8276640/>

Deutsche Zöliakie-Gesellschaft e.V.: <https://www.dzg-online.de/>

Association of European Coeliac Societies: <https://www.aoecs.org/>

German Allergy and Asthma Association e.V.: <https://www.daab.de/>

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Further information on the BfR website regarding gluten:

BfR2GO article: Gluten: Who should (not) avoid it
<https://www.bfr2go.de/ausgabe-2-2025/gluten/>

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