

3. PESTICIDE RESIDUES IN PLANT AND ANIMAL PRODUCTS

In the previous chapter, we examined the pathways through which pesticides can reach food: direct applications, uptake by plants, environmental contamination, transfer through animal feed, and the use of plant protection products during storage.

However, knowing the possible routes of contamination does not tell us which residues are actually present in food products. Answering that question requires direct analysis of foods and comparison of the results with scientifically reliable monitoring programmes.

Research shows that pesticide residues are not distributed uniformly across food categories. Fruit, vegetables, cereals, oils, processed foods and foods of animal origin have very different characteristics, which affect both the likelihood of contamination and the nature of any residues present.

Important differences can exist even within a single category. Two batches of apples, for example, may come from crops treated differently, have been harvested at different times and contain widely differing residue concentrations. The situation is even more complex when the finished product results from blending raw materials from many farms.

There is therefore no single chemical residue profile that can automatically be attributed to an entire food category. Monitoring programmes help describe the overall situation and identify the most frequent forms of contamination. But determining which residues are present in a specific food batch requires testing that batch using an appropriate sampling procedure.

3.1 What are pesticide residues in food?

The term pesticide residues refers to substances present in food products as a consequence of the use of plant protection products or other forms of exposure. A residue may consist of the original molecule, known as the active substance, or of certain transformation products. During plant growth, for example, a pesticide may be partly metabolised and transformed into other molecules. Similarly, metabolic processes in farm animals can alter substances ingested through feed or water.

For this reason, the regulatory concept of a residue does not necessarily correspond to the original molecule alone. Legislation may establish specific residue definitions identifying which compounds must be considered when checking compliance with limits or assessing risk. These definitions may encompass an active substance, certain metabolites or a sum of specified compounds, sometimes expressed as equivalents of the parent molecule.

It is important to distinguish the residue definition used for regulatory enforcement from the definition used for dietary risk assessment: they do not always include exactly the same substances. Consequently, testing solely for the parent molecule may not be enough to describe everything that legislation considers relevant.

A pesticide residue is not necessarily a single molecule: it can include a defined group of substances formed through its transformation.

3.2 Residues in fruit

Fruit is a particularly interesting food category when studying pesticides. Fruit crops may be attacked by insects, fungi and other harmful organisms at different stages of development. Crop-protection practices vary with the species, climate, pest pressure and production system. Some crops may require numerous treatments during the growing season, whereas others are managed using different programmes.

Any residues present in fruit may therefore originate from substances applied at different times. A treatment during flowering may have a different fate from one applied when the fruit is already developed. The properties of the peel also affect residue distribution. In some fruits, substances may be concentrated mainly in the outer layers; in others, they may penetrate more deeply.

Systemic pesticides introduce further differences. A pesticide absorbed by the plant can reach the fruit through its transport systems, provided its molecular properties permit this. Removing the peel therefore does not necessarily eliminate all substances.

Official European analyses show that the simultaneous presence of multiple residues is relatively frequent in certain fruit categories. In the 2024 EU-coordinated programme, published by EFSA in 2026, table grapes, grapefruit and bananas were among the products with the highest percentages of samples containing more than one quantifiable pesticide.

These findings do not mean that those products are necessarily dangerous. They do show, however, that fruit analysis can reveal mixtures of different substances even when each individual residue complies with the applicable limit.

The presence of pesticide residues in fruit cannot be inferred from appearance, smell or taste. Only appropriate analysis can provide information about the substances actually present.

3.3 Residues in vegetables

Vegetables encompass extremely different products: leaves, roots, tubers, stems, flowers, fruits and seeds. This diversity affects pesticide behaviour. Leafy vegetables, for example, have surfaces directly exposed to the environment and to any treatments applied. Their structure may favour the deposition and persistence of certain substances.

Other vegetables develop their edible portions mainly underground. In those cases, in addition to treatments applied to the crop, soil characteristics and the possibility of uptake through roots become important.

Vegetable crops may also have relatively short production cycles, sometimes involving repeated harvests. Residue distribution can therefore vary depending on when the product is harvested. Tomatoes, peppers, aubergines and other fruiting vegetables may be subject to different protection programmes, particularly against insects and fungal diseases. Leafy vegetables may present different challenges.

It is not scientifically sound to construct a universal ranking of the most contaminated vegetables without specifying the period, the origin of the products, the substances sought and the sampling programme used. Residue frequencies change over time and between different production areas.

What can be stated is that the biological and agronomic characteristics of vegetables make control strategies tailored to the different food matrices necessary.

The word “vegetables” encompasses products so different that a single generic assessment of contamination would have little scientific meaning.

3.4 Residues in cereals: wheat, maize and rice

Cereals are a fundamental part of the human diet. Wheat, maize and rice are eaten directly or processed into many products, including flours, bread, pasta, breakfast cereals and other foods.

From the perspective of pesticide residues, these crops have particular characteristics. Treatments may target seeds, soil, weeds or plant diseases during growth. The substances used and the authorised conditions depend on the crop and regulatory context.

As the grain matures, any residues present may be distributed differently among the seed's structures. In some cases they may be concentrated in the outer layers, while in others they may also be found in the inner fractions.

An important factor is the origin of the raw materials. Cereals are frequently marketed in large batches, sometimes produced by blending harvests from different fields or farms. Blending can change the distribution of residues in the final product.

Suppose, for example, that one batch of wheat contains a particular pesticide concentration and is blended with another batch containing less. The average residue concentration in the mixture may decrease. But that does not mean the substance has been eliminated: it has merely been distributed throughout a larger mass.

It is also necessary to distinguish lawful blending for technological purposes from prohibited practices intended to make products that exceed regulatory limits appear compliant. EU legislation prohibits diluting non-compliant products by blending them to artificially reduce residue concentrations below the limits.

Blending may change the average concentration of a residue, but does not demonstrate that it has disappeared. For foods made from large batches of cereals, knowing the origin and analytical composition of the final batch can therefore be particularly important.

3.5 Flour, pasta and bread: what changes during processing?

Cereal processing can significantly change residue distribution. During wheat milling, for example, the grain is separated into different fractions. The outer layers mainly contribute to bran and other by-products, whereas the inner portions form the main fraction of refined flour.

Some pesticides may be unevenly distributed among these components. Consequently, wholemeal and refined flours produced from the same raw material may contain different concentrations of particular substances.

This does not mean that refined flour is always analytically better, nor that wholemeal flour necessarily has higher contamination. The behaviour depends on the pesticide, the grain's characteristics and processing conditions.

Pasta and bread production may also change concentrations. Adding water and other ingredients changes the product's mass and can produce dilution effects. Drying, fermentation and cooking, on the other hand, may cause degradation, transformation or relative concentration of certain substances.

It is therefore important to distinguish a reduction in the total quantity of pesticide from a mere change in the concentration expressed per kilogram of food.

A processed food cannot automatically be regarded as free of pesticides that may have been present in its raw materials. To establish the actual result, analyses of the product in question or reliable scientific data on processing factors are needed.

3.6 Vegetable oils and lipophilic pesticides

Edible oils have chemical characteristics very different from those of water-rich products. They consist mainly of lipids and may favour the presence of substances with a particular affinity for fats. This property is called lipophilicity.

Some lipophilic pesticides may preferentially transfer to the oil fraction during extraction. Other, more polar compounds may follow different pathways. The outcome depends on the chemical characteristics of the substance and the production process.

In extra virgin olive oil, for example, the extraction process differs from the industrial refining used for many other vegetable oils. Certain refining operations may reduce some substances, but not all pesticides are removed to the same degree.

An oil's sensory quality and its chemical composition in terms of residues are different kinds of information. An oil may have excellent organoleptic properties and still contain pesticide residues within legal limits. Similarly, an oil in which particular residues are not quantified is not automatically superior in all other nutritional or sensory respects.

To assess analytical quality regarding pesticides, the relevant substances must be tested directly using methods suited to an oily matrix.

3.7 Residues in pulses

Pulses are an important food category because of their content of plant proteins, fibre and other nutrients. Beans, lentils, chickpeas, peas and other products may be grown under very different agronomic conditions. Plant-protection practices also vary according to species, geographical area and crop problems.

Any residues present may derive from treatments during growth or, under certain conditions, from authorised applications during storage. Drying also changes the product's water content and can affect concentrations expressed per kilogram.

Subsequent soaking and cooking may help remove certain substances or alter their distribution. However, there is no universal rule allowing complete residue elimination to be predicted.

For pulses too, it is necessary to distinguish the characteristics of the raw material, its processing and the analytical results of the finished product.

3.8 Residues in foods of animal origin

Meat, milk, eggs and other foods of animal origin may contain pesticide residues. Their presence may result from animal feed, water, environmental contamination or specific treatments used in livestock production in accordance with applicable rules.

The transfer of substances depends on their chemical properties and the animal's metabolic processes. Some compounds are transformed and eliminated quickly; others, particularly if persistent and lipophilic, may become distributed in fatty tissues.

The presence of residues in feed does not automatically entail significant contamination of meat or milk. Absorption, metabolism, elimination and exposure duration must all be considered.

Official data provide a particularly interesting perspective. In the European report for 2024, considering national programmes analysed by EFSA, 93.1% of samples of animal-origin products had no quantifiable pesticide residues according to the substances and analytical residue definitions covered by the controls. Another 6.4% contained quantifiable residues within the limits, while 0.5% exceeded the maximum limits.

This is an important finding: for the substances sought and under the monitoring conditions considered, quantifiable residues were less frequent than in many plant-product categories.

It does not, however, mean that 93.1% of all foods of animal origin were free from every contaminant. The finding concerns the samples and substances analysed, not the entire range of chemical compounds potentially present.

The absence of quantifiable pesticides in a sample does not automatically demonstrate the absence of other contaminant groups, such as PFAS, dioxins or metals.

3.9 Milk and eggs: two particular matrices

Milk and eggs deserve specific consideration. Milk contains an aqueous phase and a lipid component, whose relative proportions vary with the animal species and product. Some lipophilic contaminants may be distributed preferentially in the fat fraction.

This does not mean that all substances behave in the same way. More water-soluble compounds may have different distributions, while others are metabolised before reaching the milk.

Eggs are another complex matrix. The yolk contains lipids and may act as a distribution compartment for certain persistent substances. Egg white, by contrast, is composed mainly of water and proteins. Here too, distribution depends on the compound.

The animals' diet and farming environment can affect exposure, but farming methods alone cannot predict with certainty which residues will be present. A production system may follow strict practices while still being exposed to pre-existing environmental contamination.

Information about farming methods may therefore be complemented by appropriate analyses to understand the final chemical composition.

3.10 Fish and aquatic products

Fish introduce additional complexity because they live in environments that can receive contaminants from many sources. Pesticides can reach rivers, lakes and seas through runoff, discharges and environmental transport. Some persistent substances may bind to sediments or enter aquatic organisms.

Behaviour depends on the molecule, environmental characteristics and species involved. In fish, uptake, metabolism, elimination and, for certain substances, bioaccumulation may be important processes.

However, chemical contamination of fishery products is not limited to pesticides. Other contaminants, such as mercury, dioxins, PCBs and PFAS, follow different pathways and are subject to specific regulatory and scientific assessments.

It would therefore be incorrect to use a negative pesticide test result to draw general conclusions about the overall chemical quality of fish. Every family of contaminants requires appropriate testing methods and interpretation criteria.

3.11 What do European controls show?

Official European programmes are among the principal sources of information on pesticide residues in food. EFSA collects and analyses results submitted by national authorities and uses them to describe the residue situation on the European market.

The report on samples taken in 2024, published in May 2026, includes an EU-coordinated programme and national programmes also based on risk criteria.

The coordinated programme tested 9,842 samples from twelve food categories. In 43.1% of samples, none of the pesticides sought was quantifiable. Another 54.5% contained one or more quantifiable residues within the applicable limits. Numerical exceedances of maximum residue limits occurred in 2.4%, while 1.2% were found non-compliant after measurement uncertainty had been taken into account.

A further important result concerns the simultaneous presence of different substances: 34.9% of samples contained more than one quantifiable pesticide. Among the twelve categories analysed, the highest percentages of samples with multiple residues were observed in table grapes, grapefruit and bananas.

These data demonstrate that multiple residues are not an exceptional occurrence in the products studied. At the same time, most samples complied with legislation, and EFSA's risk assessments generally indicated low levels of concern under the scenarios considered.

The two findings are not contradictory. A system may frequently detect pesticide residues and, at the same time, assess the dietary risk associated with estimated exposures as low.

The first statement concerns the presence of substances; the second concerns a toxicological assessment of the quantities ingested. Confusing them leads to an incomplete interpretation of scientific findings.

Pesticide residues in EU food controls

EU coordinated programme, 2024 — 9,842 samples, 12 categories

Overall results



● No quantifiable residues	43.1%
● Residues within MRLs	54.5%
● MRL exceedances	2.4%

Non-compliant after measurement uncertainty: 1.2%

Samples with multiple residues: 34.9% overall

Categories with particularly frequent multiple residues:

Table grapes		77.9%
Grapefruit		73.5%
Bananas		66.1%

Interpretation: detection does not by itself establish health risk.

Most samples complied with legal limits; risk depends on exposure.

Source: EFSA, 2024 EU report (published 2026). Data reproduced from the Italian chapter.

3.12 What cannot be inferred from statistical data?

Monitoring programmes provide valuable information, but must be interpreted in light of their design. Representative sampling can estimate how frequently certain characteristics occur in the population of products considered. Controls targeted at products believed to carry greater risks have a different purpose.

Results obtained through different sampling designs cannot be compared without taking those differences into account.

It is also essential to know which substances were sought. A laboratory may test for hundreds of pesticides, but that does not mean every potentially present molecule was investigated. Methods may also have different limits of quantification depending on the substance and the food product.

A result below the limit of quantification therefore does not prove the absolute absence of the compound.

Finally, a monitoring programme does not analyse every individual batch placed on the market. Its results may rigorously describe the general situation without providing direct information about the product a particular consumer is buying.

This limitation does not necessarily arise from a deficiency in the system; it follows from its purpose and from the enormous volume of food that must be controlled.

Statistics provide knowledge about the market. Testing a batch provides knowledge of that particular batch, within the limits of sampling and the analytical method. These are different and complementary forms of knowledge.

3.13 Is product origin enough to predict contamination?

Country of origin, production system and traceability provide important information. They help reconstruct the history of raw materials and identify the general conditions in which they were produced.

They do not, however, automatically reveal the concentrations of residues present. Farms within the same region may follow very different practices. One producer may use particular treatments while another does not. Soils may have different environmental histories. Weather conditions may alter the dispersal, degradation and transfer of substances.

Organic certification, too, describes a regulated production system but does not constitute analytical proof of the universal absence of residues.

Information about origin and production method remains valuable, but has a different purpose from chemical analysis of the finished product.

Knowing where and how a food was produced helps explain its history. Analysing it reveals part of its actual composition.

3.14 From residue control to knowledge of chemical quality

Compliance with maximum residue limits is a fundamental condition for the lawful marketing of food, but it is not necessarily a criterion of analytical excellence.

Two batches of the same raw material may both comply with legislation yet contain very different concentrations of the same pesticide. One batch may contain several quantifiable residues, each within its respective limit. Another may have no quantifiable residues of the substances tested.

This difference does not automatically prove that either product is dangerous. Nevertheless, it is concrete information that consumers may wish to know.

A voluntary analytical protocol may adopt criteria stricter than legal requirements. It may select batches in which specified substances are not quantifiable at declared limits, or test for families of contaminants not normally included in routine controls of that matrix.

Such protocols also have limitations. Results depend on sampling, the list of substances investigated, laboratory performance and the representativeness of the material analysed. They cannot demonstrate that a food is free of every undesirable substance, but they can substantially expand the

information available.

Regulatory compliance describes whether a legal requirement is met. Analytical knowledge can distinguish products that, while all compliant, may have different chemical compositions.

Conclusion to Chapter 3

Pesticide residues may occur in many categories of plant and animal foods, but their distribution varies substantially with the substances involved, matrix characteristics, production practices and environmental conditions.

Fruit, vegetables, cereals, oils, pulses and processed products present different challenges. Foods of animal origin may also contain residues, particularly when substances can move through the food chain or become distributed in tissues.

European monitoring programmes demonstrate that quantifiable residues are relatively common in several plant-product categories, while controls on animal products generally show lower frequencies for the substances considered.

In most official samples examined, residues comply with regulatory limits. But compliance does not mean absence. And statistical knowledge of the overall situation is not equivalent to analytical knowledge of an individual product.

Food safety requires scientific risk assessments. More informed food choices may also require information about the substances actually present.

Understanding which residues are found in food is therefore an important step. But a further question remains: what happens to these substances over time? Some disappear quickly; others persist; still others are transformed into different molecules.

To understand these transformations, it is necessary to study pesticide persistence, degradation and metabolites.

Scientific and regulatory sources

EFSA — The 2024 European Union Report on Pesticide Residues in Food, published 5 May 2026.

<https://doi.org/10.2903/j.efsa.2026.10054>

EFSA — Pesticide residues in food: latest data released.

<https://www.efsa.europa.eu/en/news/pesticide-residues-food-latest-data-released>

EFSA — Interactive data visualisation on pesticide residues, 2024 report.

<https://multimedia.efsa.europa.eu/pesticides-report-2024>

Regulation (EC) No 396/2005 — Maximum residue levels of pesticides in food and feed.

<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32005R0396>

European Commission — EU Pesticides Database.

https://food.ec.europa.eu/plants/pesticides/eu-pesticides-database_en

EFSA — Pesticides.

<https://www.efsa.europa.eu/en/topics/topic/pesticides>