

10. WHAT DO ANALYSES REALLY DEMONSTRATE?

A NUMBER CAN TELL A STORY. BUT NOT ALWAYS THE WHOLE STORY.

Imagine walking into a laboratory specialising in food analysis.

On the bench are two samples: a broccoli and an apple.

Both are being tested for the presence of residues associated with plant protection products.



Carbon disulphide, CS_2 , is detected in the broccoli. It is used as an indicator in the determination of various dithiocarbamates.

In the apple, a measurable concentration of phosphonic acid is detected instead.

At first glance, the conclusions might seem straightforward.

The broccoli was treated with a dithiocarbamate. The apple was treated with fosetyl-aluminium or a product containing phosphonates.

But can we be certain?

Having read the previous chapters, we know that the answer is no.

The CS₂ could also come from compounds naturally present in broccoli. The phosphonic acid could originate from different agricultural sources or have been absorbed from the soil following treatments applied to previous crops.

The laboratory may have measured both substances correctly without being able to establish with certainty what caused their presence.

This is one of the most interesting lessons of analytical chemistry: a numerical result can be extremely reliable without, on its own, providing a complete explanation of the phenomenon observed.

THE THREE QUESTIONS WE MUST NOT CONFUSE

When analysing a food, we can ask at least three fundamental questions.

The first is: which substance is present, and at what concentration?

The second is: where does that substance come from?

The third is: what consequences might its presence have for health?

These questions seem closely connected, and indeed they are.

But they require different tools and knowledge.


Overorganic
library

The three questions of food analysis

Three different levels we must not confuse

1 What is present and how much?

Food analysis **identifies** the substances present in the sample and measures their **quantity**, usually expressed in mg/kg (ppm) or µg/kg (ppb). The result indicates a specific residue and its concentration.



Residue
0.015 mg/kg

2 Where does it come from?

The residue may have different origins: it may derive from an **agricultural treatment** (e.g. plant protection product), it may be of **natural origin** (produced by the plant), or it may come from **environmental contamination** or from **other stages of the supply chain**. The history of the product and the production practices help us interpret its origin.



3 What risk does it involve?

To assess the risk, we need to consider **exposure**, that is, the amount that may be ingested through the diet, the **dose** in relation to toxicological reference limits (e.g. Acceptable Daily Intake, ARfD), and the **overall context**. The analytical result therefore acquires **significance for consumer health** only within this assessment.



 **An analytical result alone does not answer all three questions.**
To understand the meaning of a food residue, identification and quantity, origin, and risk assessment must be considered together.

To answer the first, we mainly use analytical chemistry.

To answer the second, studies of substance metabolism, agronomic information, environmental data and records of treatments may be needed.

To answer the third, we must turn to toxicology and dietary exposure assessment.

An analytical certificate can provide a very precise answer to the first question, but not necessarily to the other two.

Understanding this distinction is essential for interpreting food controls correctly.

THE CASE OF DITHIOCARBAMATES: WHEN WE MEASURE AN INDICATOR

Let us return to dithiocarbamates.

As we have seen, many traditional analytical methods do not directly identify individual active substances.

The sample undergoes a chemical reaction that releases carbon disulphide.

The amount of CS₂ is then measured and used to express the result.

This approach has undeniable analytical value, but it has two limitations.

The first is that different dithiocarbamates can produce the same compound during the reaction.

The second is that certain natural components of plants, particularly in some botanical families, can contribute to the formation of CS₂.

The result therefore does not necessarily identify the active substance responsible.

This is particularly important because mancozeb, metiram, ziram and other dithiocarbamates do not have identical toxicological properties.

Knowing only the overall CS₂ value may not be sufficient to attribute the residue to a specific substance.

EFSA explicitly addressed this difficulty in its review of maximum residue levels published in 2023.

The experts also considered background levels attributable to substances naturally present in plants, acknowledging the uncertainties involved in interpreting the results.

This does not make analyses useless.

It means their results must be interpreted with an understanding of the characteristics of the method used.

THE CASE OF PHOSPHONIC ACID: WHEN THE ORIGIN IS UNCERTAIN

In the case of phosphonic acid, the situation is different.

The laboratory can directly identify the substance present in the food sample.

There is no need to convert different fungicides into a common indicator, as happens with the traditional dithiocarbamate method.

The difficulty mainly concerns its origin.

Phosphonic acid may be associated with the use of fosetyl-aluminium, potassium phosphonates and disodium phosphonate.

It may also originate from other agricultural sources and, under certain conditions, be absorbed from the soil even by crops grown after those that were treated.

Imagine two apples, both containing 0.5 mg/kg of phosphonic acid.

The concentration is identical, but the history of the two apples could be completely different.

One may come from an orchard treated with a plant protection product containing phosphonates.

The other may have absorbed residues present in the soil without having received that treatment directly.

The laboratory may report the same result for both.

To distinguish their origins, it may be necessary to know the treatment history and agronomic conditions.

EFSA studies have documented the persistence of phosphonic acid in soil and the possibility of its transfer to rotational crops.

The presence of a substance is an analytical fact. Reconstructing its origin requires further scientific investigation.

WHEN TWO IDENTICAL RESULTS DO NOT MEAN THE SAME THING

Now imagine two laboratories analysing the same food.

Both report the concentration of a substance in milligrams per kilogram.

We might think that, because the unit of measurement is the same, the results are automatically comparable.

This is not always the case.

Before comparing two results, we need to know what was actually measured.

For example, in traditional methods for dithiocarbamates, the result may be expressed as CS₂.

For phosphonates, by contrast, phosphonic acid is determined, under a regulatory residue definition that also includes its salts.

We are therefore not measuring the same thing.

Even within the same family of substances, methods may differ in sample preparation, sensitivity, selectivity and the way results are expressed.

For this reason, an analytical certificate should always be interpreted alongside information about the method used.

A number, without the analytical context in which it was obtained, risks being misunderstood.

WHAT THE LIMIT OF QUANTIFICATION MEANS

One of the most important elements of an analytical certificate is the limit of quantification, generally abbreviated to LOQ.

It is the lowest concentration at which the method used can quantify a substance with performance considered acceptable.

Imagine a laboratory using a method with an LOQ of 0.01 mg/kg.

If the result is below this value, it means that the method has not reliably quantified the substance at that concentration.

But it does not necessarily mean that the substance is completely absent.

It could be present at a concentration below the method's quantitative capability.

This is a fundamental distinction.

Not quantifiable does not necessarily mean non-existent.

The concept becomes especially important when looking for foods characterised by very low residue levels.

Two laboratories might analyse the same sample using methods with different limits of quantification.

One laboratory might be unable to quantify a substance that another, using a more sensitive method, is able to measure.

This does not necessarily mean that either laboratory has made a mistake.

It means that the methods have different analytical capabilities.

Naturally, the limit of quantification must be appropriate for the purpose of the analysis, and the method must be properly validated.

SENSITIVITY AND SPECIFICITY: TWO DIFFERENT QUALITIES

We might think that the best method is simply the one capable of measuring the lowest concentrations.

But sensitivity alone is not enough.

Suppose we use an extremely sensitive method to measure CS₂.

We might detect minute amounts of the compound.

However, if the method does not distinguish CS₂ generated from fungicides from that derived from natural components of the food, greater sensitivity does not resolve the problem of origin.

Indeed, it may make the natural contribution more apparent as well.

For this reason, the quality of a method must be assessed by considering several parameters.

These include selectivity, precision, accuracy, limits of detection and quantification, and measurement uncertainty.

Selectivity is the ability of the method to distinguish the target compound from other substances present in the sample.

Precision describes how close the results obtained from repeated measurements are to one another.

Accuracy concerns how close the result is to the reference value, taking systematic and random errors into account.

These are different characteristics, and all are important.

A highly sensitive but poorly selective method may not be the most suitable for answering a question that requires the identification of a specific molecule.

WHAT DOES EXCEEDING A LEGAL LIMIT MEAN?

Imagine a food containing a residue concentration above the maximum level laid down by European legislation.

The product may be found to be non-compliant.

But does this necessarily mean that it is dangerous?

Not always.

Maximum residue levels, or MRLs, are established on the basis of the agricultural conditions considered and scientific assessments of consumer safety.

They do not necessarily represent the concentration at which a toxic effect begins.

Exceeding a limit may therefore constitute a regulatory breach without automatically implying an immediate health risk.

Conversely, a compliant food may contain measurable amounts of residues.

Regulatory compliance and risk assessment are two different matters.

To determine risk, it is necessary to consider the toxicity of the substance, its concentration and the amount consumed through the diet.

In the case of dithiocarbamates, the assessment may also be complicated by the difficulty of attributing CS₂ to a particular active substance.

In the case of phosphonic acid, by contrast, the residue can be measured directly, but its origin cannot always be identified.

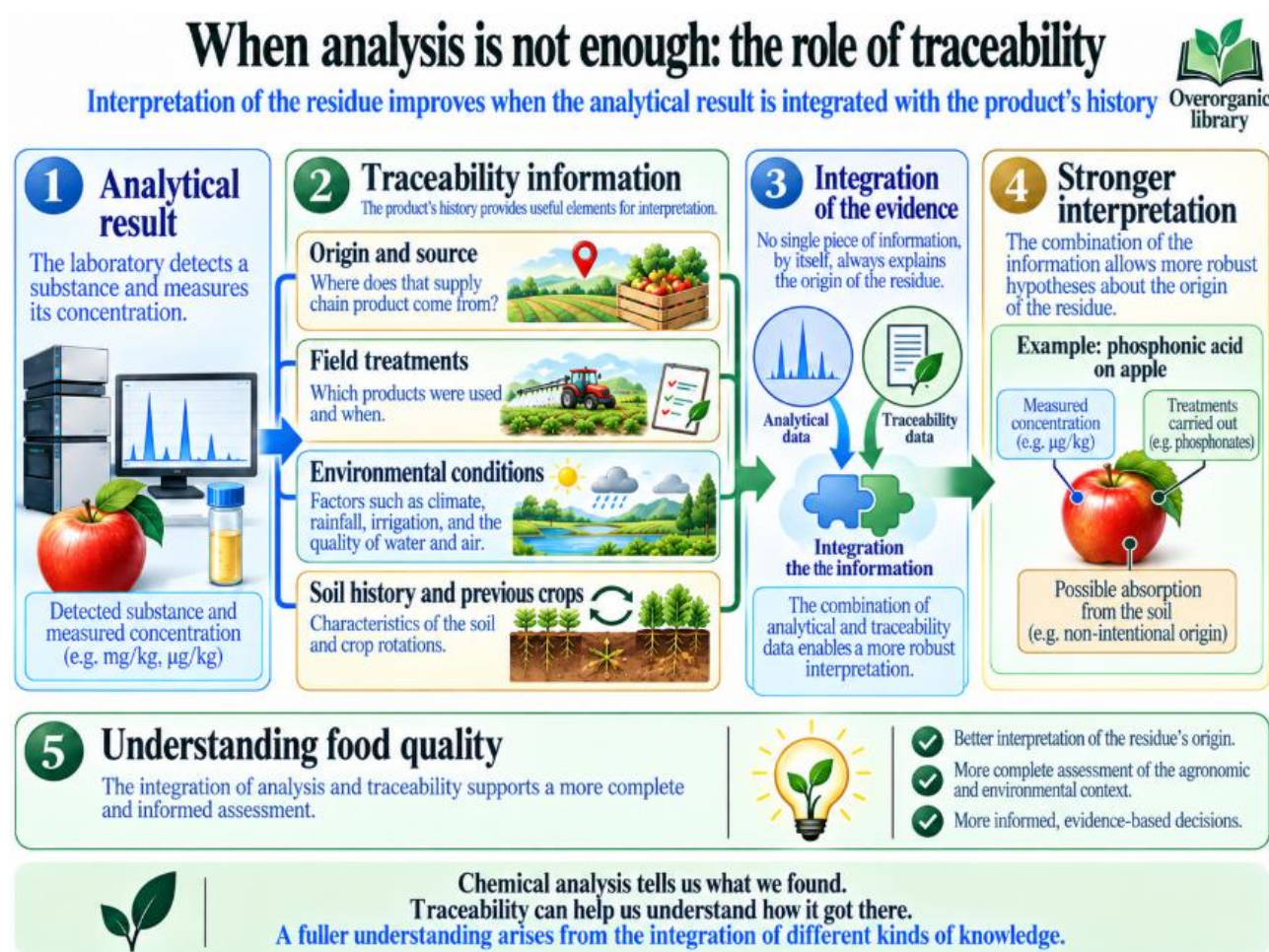
In both cases, the control system must take account of the characteristics of the method and the regulatory residue definition.

WHEN ANALYSIS IS NOT ENOUGH: THE ROLE OF TRACEABILITY

We have seen that a laboratory can identify and quantify a substance without necessarily establishing where it comes from.

So how can we obtain more complete information?

Part of the answer lies in traceability.



Knowing the origin of a food, the products used during cultivation, the environmental conditions and the history of the soil can help us interpret analytical results.

Let us consider phosphonic acid again.

If we find this substance in a fruit, the laboratory result tells us its concentration.

If we also know which treatments were applied in the field, we can develop better-founded hypotheses about its origin.

And if we have information about previous crops, we can also assess the possibility of uptake from the soil.

None of these pieces of information, considered in isolation, always allows us to reach a definitive conclusion.

But combining them can considerably improve the quality of the investigation.

Chemical analysis tells us what we have found. Traceability can help us understand how it got there.

It is the integration of different kinds of knowledge that allows a fuller understanding of food quality.

THE VALUE OF OFFICIAL CONTROLS

At this point, a doubt might arise.

If analyses have interpretative limitations, can we really trust food control systems?

The answer is yes, provided we correctly understand what these systems are designed to verify.

The European Union has a comprehensive system for monitoring pesticide residues, based on validated analytical methods, competent laboratories, shared procedures and scientific assessments.

EFSA collects and analyses control results, assesses risks to consumers and highlights the uncertainties arising from the available knowledge.

The European Union reference laboratories contribute to the development and harmonisation of analytical methods.

It is a scientifically structured system that has made a significant contribution to protecting health and improving knowledge about the presence of residues in food.

But no control system can eliminate scientific uncertainty completely.

Many substances are tested for, analytical methods have different limitations, and toxicological knowledge continues to evolve.

The case of dithiocarbamates clearly demonstrates this.

In its 2023 review, EFSA itself acknowledged the difficulties involved in identifying individual active substances, natural CS₂ levels and the information still missing to complete some risk assessments.

In the case of phosphonates, scientific assessments have led to changes in the regulatory residue definition, precisely to make it more consistent with the behaviour of the substances in food.

Recognising the limitations of a scientific system does not mean denying its value. It means understanding how it works and where it can be further improved.

FROM COMPLIANCE TO KNOWLEDGE

Imagine standing in front of a supermarket shelf.

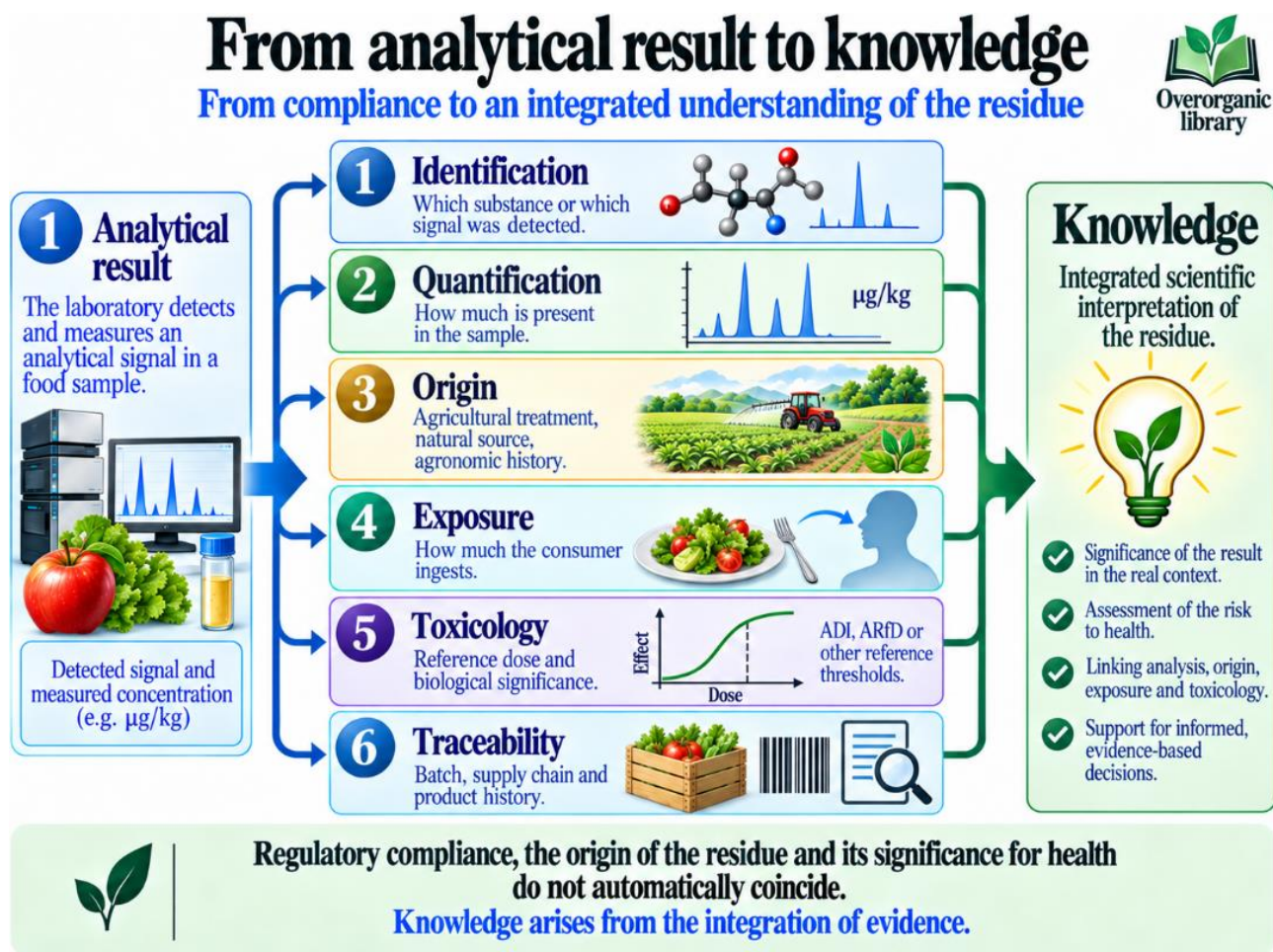
Two packs of apples are of the same variety, come from different producers and both comply with European legislation.

Legally speaking, both can be sold.

But do we know whether they contain the same residues?

Not necessarily.

One might contain measurable concentrations of certain substances, while in the other those same substances might be below the limits of quantification of the methods used.



Both may be compliant while having different analytical characteristics.

This information may be of interest to a consumer who wishes to understand more thoroughly the composition of the food they buy.

Naturally, a smaller number of quantified substances does not automatically demonstrate that a food is healthier, nor does it guarantee the absence of every contaminant.

The result also depends on the substances tested for, the representativeness of the sampling and the limitations of the methods used.

Nevertheless, knowing the analytical results adds information that a simple declaration of regulatory compliance does not always provide.

This is an important distinction.

Legislation establishes the conditions under which a food may be marketed.

A more in-depth analytical investigation can instead describe some of its characteristics in greater detail.

These two approaches should not be set against each other.

They can complement one another.

AN ANALYTICAL RESULT IS NOT AN ABSOLUTE TRUTH

Science advances through measurements, experiments, comparisons and verification.

But every measurement has a defined scope of validity.

An analytical result concerns a particular sample, analysed at a particular time, using a method with known characteristics.

It does not necessarily describe every individual portion of an entire harvest.

Residues may, in fact, be distributed unevenly.

Two fruits from the same plant may have different concentrations, just as two samples taken from different parts of a food lot may differ.

For this reason, sampling is a fundamental stage of the control process.

Even a highly accurate analytical method cannot fully compensate for an unrepresentative sample.

Furthermore, an analysis performed today does not necessarily describe every transformation that might occur during subsequent storage or processing of the product.

The quality of the information therefore depends on the entire procedure: from the selection of the sample to the interpretation of the result.

A number acquires scientific meaning only when we know the conditions under which it was obtained.

WHAT HAVE WE LEARNT FROM DITHIOCARBAMATES AND PHOSPHONATES?

We began with two families of substances used to protect crops against disease.

We traced their journey from application in the field to the presence of residues in food.

We discovered that some dithiocarbamates can break down into degradation products, such as ETU, which have toxicological properties of their own.

We saw that the traditional method based on CS₂ determination can encounter difficulties in identifying individual active substances and interpreting certain results.

We then explored fosetyl-aluminium and phosphonates, discovering that they can leave a common residue: phosphonic acid.

This substance can persist in soil, be absorbed by subsequent crops and originate from different sources.

Finally, we examined health effects and understood that not all substances used as fungicides have the same toxicological profile.

It has been a journey through chemistry, biology, agronomy and toxicology.

Above all, however, it has been a journey through the meaning of scientific information.

Because knowing that a substance is present does not necessarily mean knowing its origin.

Knowing its origin does not automatically mean knowing the risk.

And knowing the risk does not mean that all scientific uncertainty has been eliminated.

FOOD SAFETY BEGINS WITH KNOWLEDGE

Every day, millions of people buy food relying on the information available: origin, ingredients, expiry date, certifications and statements on packaging.

This information is important.

But the chemical composition of food may also include substances that we cannot see, smell or recognise by taste.

Identifying them requires analytical instruments.

Understanding their significance requires scientific knowledge.

And communicating the results correctly requires distinguishing facts from hypotheses, certainties from uncertainties, and regulatory compliance from the characteristics actually measured.

No single analysis can tell us everything about the quality of a food.

Nor is there any single parameter capable of fully summarising its safety.

But every scientifically sound piece of information can help improve our knowledge.

And this is precisely the deeper meaning of a library dedicated to food contaminants.

Not treating every detected substance as a danger, nor considering every investigation unnecessary whenever a food complies with the law.

Rather, learning to read what science shows us, understanding both the strength of its knowledge and its limitations.

Because the first step towards an informed choice is not having all the answers.

It is learning to ask the right questions.

SCIENTIFIC REFERENCES FOR CHAPTER 10

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