

Mysterious substances

What are secondary plant substances?

What are apples made of? Water – obviously. Sugar, say those who count calories. And then there's the dietary fibre. Most of us know that much. But what about the aroma of apples? What about the taste? What makes one apple yellow and another red? All of this is determined by tiny amounts of many different substances which only reveal themselves at second glance and are therefore known as “secondary plant substances”, a nomenclature that is bad for their image. The term “bioactive substances” sounds much more positive. It implies a feature that science only gradually began to perceive: these substances make an impact. They may be short on volume, but they are big on efficacy. In fruit, vegetables and seeds, they are responsible on the one hand for vibrant colours, attractive aromas and a fine taste whilst, on the other, they avert danger and protect against being eaten up. And if they fail in the last instance, the substances keep up the good work in the bodies of people and animals. By activating enzymes or protecting certain substances from being destroyed by oxidation, for example, they leave behind their traces in various different ways – traces that are often very important for health. Certain secondary plant substances can reduce

the likelihood of contracting cancer, other have a positive effect on the cardiovascular system. Many of these effects have still not been investigated; countless secondary plant substances have not found their way into the focus of research at all. Given that, so far, more than 60,000 secondary plant substances have been identified, it is not difficult to understand why we do not yet know – and perhaps never will – which substances have an effect and in which combinations and concentrations. But there is certainly enough scientific evidence to confirm that these substances, which occur in minimal quantities in all plant-based foods, are important for health. If you want to eat healthily, you should ditch the pills and multivitamin cocktails and make vegetables and fruit the main course rather than the side dish. And it is not even a “sacrifice” – it makes your diet varied and tasty.

Colour aroma and taste

The colourful world of secondary plant substances

The celebrities amongst the secondary plant substances are undoubtedly the anthocyanins. It is difficult not to notice this sub-group of bioactive substances: being the representatives of the polyphenols they are majorly responsible for the glorious colours of fruit and vegetables. Together with the carotenoids, they produce the most diverse shades of red that so exquisitely adorn red cabbage, red onions, aubergines as well as radicchio lettuce. The yellow in yellow peppers and the orange in carrots also have this secondary plant substance to thank for their colouration.

Yet other secondary plant substances, particularly from the group of monoterpenes, give lemons and oranges their aroma. There are abundant aromatic monoterpenes in the world of bioactive substances and even a minimal variance in the molecules can produce aromas as different as dill and mint. Indeed, the molecule of both herbs' main aromatic substance is nearly identical. But only nearly: the substances are mirror images of one another. If such a minimal difference in composition can produce such a major difference in effect, it requires no great leap of the imagination to appreciate that a differing composition of secondary plant substances also has an impact on the

resulting taste. And this composition not only differs from plant species to plant species, but in some cases, even from fruit to fruit on one and the same plant. The issue of whether the fruit has ripened in direct sunlight or in the shade has an effect on the formation of secondary plant substances. So, it comes as no surprise that this inconceivable wealth of variants alone means that it is not possible to elucidate what impact which of the individual substances has or which substance can be ascribed to what composition on a case-by-case basis. It is at least good to know that there is plenty of good evidence to support the cardinal message: eating fruit and veg benefits your health – even if scientists do not know down to the finest detail, how and why this is the case.

The opposite of harmful

Secondary plant substances do you good

It is an enormous scientific challenge to prove that certain substances in food reduce the likelihood of contracting a disease. The environmental impacts, genetic predisposition and habits that affect people's lives are inextricably bound up and make it very difficult to identify the actual cause when diseases like cancer or cardiovascular disorders, which take decades to develop, do break out. To unequivocally establish why someone does NOT get a certain disease is completely impossible.

If we are going to make verifiable statements on the effects of foodstuffs on human health, it is essential to conduct scientific studies on people. However, those participating in such studies cannot be expected to commit long-term and restrict their dietary habits indefinitely. Which means nutrition scientists essentially only have two options for investigating the significance of nutrition:

Number One: to compare one very large group of people who have a specific diet (a large intake of vegetables and fruit, for example) with another group that has completely different dietary habits (a very small intake of vegetables and fruit). Are there differences in the frequency with which certain diseases occur? This is known as the

epidemiological approach. Number Two: to try to find a measurable medical sign in the body (such as blood pressure) which is related to the question under discussion, e.g. the development of a disease (the search for biomarkers).

Both methods have their shortcomings but, particularly if they are combined and repeatedly produce the same results, they do provide clear indications. Just like in a trial based on circumstantial evidence, the arguments are pieced together until a reliable outcome has been achieved.

And when it comes to the consumption of fruit and vegetables, we really do have such clear indications: The more often fruit and vegetables are eaten, whether raw or cooked, the less the likelihood of contracting cardiovascular diseases and certain types of cancer like colon cancer.

A comet tail points the way

Evidence of good nutrition

There is a relatively quick and easy way of demonstrating the effects of certain foodstuffs on cell health. It is called “Comet Assay”. In every cell in the body there is a cell nucleus containing DNA which carries all the genetic information. Environmental impacts constantly cause damage to DNA, but so do normal metabolic processes. The strands of the double helix can break, its structure can be changed and then it is susceptible to mutations. An example of one potential cause of serious DNA damage is sunburn. If a person is healthy, the damage is immediately repaired or the seriously-damaged cells are removed. The greater the damage and the lesser the body’s ability to repair it, the greater the probability that diseases like cancer will arise.

The constituents of certain foodstuffs can help to repair damage effectively – or even prevent it from happening in the first place. In order to measure this, cells are initially isolated and their DNA visualised. Scientists then intentionally damage the DNA by adding an aggressive chemical substance like hydrogen peroxide to assess how well the repair system functions. With the help of electrophoresis, it is possible to see the fragments of DNA accruing in the cell nucleus. The result is reminiscent of the tail

of a comet (whereby the cell nucleus represents the comet) and its surface can be measured. The Max Rubner Institute has conducted experiments using apples and apple juice which reveal that eating apples helps to prevent DNA damage. Furthermore, the apples eaten also ensure that the cells are better able to protect DNA against damage. The effect can be measured within just 24 hours. The more apples you eat, the more obvious the effect – but even just one apple makes a difference.

In short

Glossary

Secondary plant substances or bioactive substances

are substances that occur in plants in very tiny quantities and belong to quite different chemical groups but have a very important function in these plants as well as in animals and humans. Primary plant substances are carbohydrates, proteins and fats.

Bioavailability

indicates how much of a substance that has entered the body is available. Some secondary plant substances are consumed in comparatively large amounts during food intake but are excreted again “unused”. Bioavailability can sometimes be improved by processing, for example pureeing or steaming. In the case of carotenoids in carrots, availability can be considerably improved by adding some fat.

Healthy – poisonous

In small quantities, many secondary plant substances have a positive effect – in large quantities, the reverse can happen. The quantities of secondary plant substances that are consumed with an ordinary diet, however, are not a problem. Poisonous secondary plant substances in vegetables are often rendered harmless or removed during

standard processing: by cooking beans, for example, or cutting off the green parts of potatoes.

Pill or matrix

Apparently, it is quite easy to buy individual secondary plant substances in the form of tablets and consume them this way. However, we have still not been able to ascertain definitively what amounts of which substances, and above all which combinations, achieve the positive effects that have already been determined. Consequently, we do not know which secondary plant substances would have to be contained in a pill to make it effective. Since too much of certain substances can be dangerous, tablets containing isolated substances are not to be recommended. In the natural food matrix – that is, in fruit, vegetables, cereals and vegetable oils – secondary plant substances have been proven to be beneficial for health.

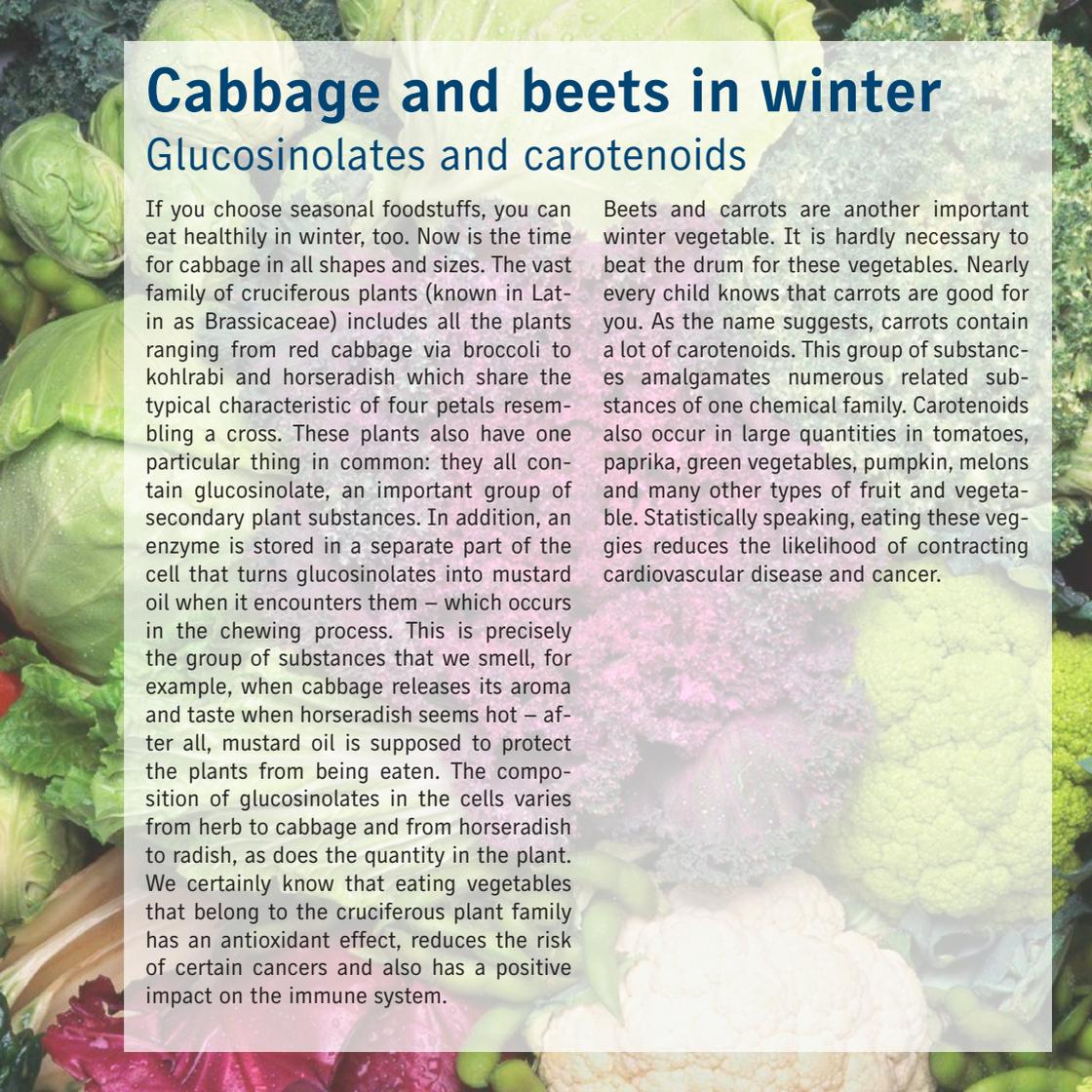
A vibrant collage of fresh fruits, including raspberries, strawberries, blueberries, and cherries, filling the background of the page. The fruits are arranged in a dense, overlapping pattern, with some showing their characteristic textures and colors like the red of the raspberries and strawberries, the blue of the blueberries, and the dark red of the cherries.

Fresh fruit in summer

Polyphenols to get your teeth into

Strawberries, raspberries, blackberries, cherries, grapes – what would the summer and autumn be without fresh fruit? All these fruits as well as other vegetable and fruit species contain secondary plant substances, some of which belong to the huge group of polyphenols. Yellow, red, violet, right through to blue – the colourful potpourri of fruit is very largely determined by flavonoids, especially the sub-group of anthocyanins. For their part, flavonoids belong to the polyphenols which provide the fruit with important protective substances. They prevent sunlight and oxygen from destroying the cells. Of course, they can only do so if they occur in sufficiently high concentrations in the fruits' boundary layers – one good reason for not peeling apples. And when it comes to wine, there is a good reason for choosing red rather than white because the grape skins transport more of the valuable substances into the wine with the colour. Polyphenols are also considered particularly valuable for human health. They are reported to have a positive effect on the vascular system and thus reduce the risk of contracting cardiovascular disease. But no-one has yet managed to ascribe these effects to a specific substance or group of substances amongst the polyphenols. So,

the message is the same here, too: isolated single substances in the form of tablets can do more harm than good – the best way of preventing disease by nutrition is to eat colourful fruit and tasty vegetables as well as nuts and seed oils. Sometimes raw, sometimes cooked, always varied.

A vibrant collage of various winter vegetables including cabbages, beets, and carrots. The background is a dense arrangement of these fresh produce items, with a semi-transparent white box overlaid in the center containing text.

Cabbage and beets in winter

Glucosinolates and carotenoids

If you choose seasonal foodstuffs, you can eat healthily in winter, too. Now is the time for cabbage in all shapes and sizes. The vast family of cruciferous plants (known in Latin as Brassicaceae) includes all the plants ranging from red cabbage via broccoli to kohlrabi and horseradish which share the typical characteristic of four petals resembling a cross. These plants also have one particular thing in common: they all contain glucosinolate, an important group of secondary plant substances. In addition, an enzyme is stored in a separate part of the cell that turns glucosinolates into mustard oil when it encounters them – which occurs in the chewing process. This is precisely the group of substances that we smell, for example, when cabbage releases its aroma and taste when horseradish seems hot – after all, mustard oil is supposed to protect the plants from being eaten. The composition of glucosinolates in the cells varies from herb to cabbage and from horseradish to radish, as does the quantity in the plant. We certainly know that eating vegetables that belong to the cruciferous plant family has an antioxidant effect, reduces the risk of certain cancers and also has a positive impact on the immune system.

Beets and carrots are another important winter vegetable. It is hardly necessary to beat the drum for these vegetables. Nearly every child knows that carrots are good for you. As the name suggests, carrots contain a lot of carotenoids. This group of substances amalgamates numerous related substances of one chemical family. Carotenoids also occur in large quantities in tomatoes, paprika, green vegetables, pumpkin, melons and many other types of fruit and vegetable. Statistically speaking, eating these vegetables reduces the likelihood of contracting cardiovascular disease and cancer.

Fresh is not always best

It's the mixture that does it

When people are talking about the health benefits of fruit and vegetables they often immediately think of Vitamin C. Thanks to the “human studies” involuntarily delivered by early seafaring, it was soon discovered that this substance was vital. Research into secondary plant substances, on the other hand, is only a few decades old. But such a short time has sufficed to recognise that this incredibly diverse group of substances fulfils eminently important functions for human beings. Unlike Vitamin C which soon loses some of its impact when processed, there are secondary plant substances that are so tightly bound to the cell walls that, irrespective of quantity, they become more available to the human metabolism when the fruit or vegetable is cooked. This is true, for example of the carotenoid lycopene which together with other substances is responsible for making tomatoes bright red. Lycopene is comparatively heat-stable so that it can still maintain its efficacy in soup, sauce, or even in ketchup. The situation is quite different when it comes to two other representatives of the carotenoids, lutein and zeaxanthin, which can be found, amongst others, in kale. Depending on the method of cooking, steaming or boiling in water, about 20-80 per cent of this carotenoid are lost.

What starts in the group of carotenoids, continues in one group of substances after another: there is no hard and fast rule about how the processing impacts secondary plant substances in general – which is why, in the end, the old nutrition adage holds true: eating a lot of fruit and vegetables, fresh and cooked and full of variety, is good for your health. This is one rule that has retained its validity unchanged ever since it was first formulated and one that ideally complies with our expectations with regard to good food.

MRI



Max Rubner-Institut

The mission of the Max Rubner Institute (MRI), Federal Research Institute of Nutrition and Food, is to support the Federal Ministry of Food and Agriculture (BMEL) in its decision-making by delivering scientifically-sound statements as well as to expand knowledge in the field of nutrition and food research “for the benefit of the common good”. One important, scientifically well-documented key message is that a balanced diet is fundamentally good for health, which means eating foodstuffs from all food groups. A diet involving a large proportion of fruit and vegetables – whether raw or cooked – and not too much meat, especially processed meat, is particularly healthy. Overall, the relationship between movement and other means of expending energy must be balanced with energy intake.

With its four sites, the Max Rubner Institute falls within the remit of the Federal Ministry of Food and Agriculture. In the context of this remit it is scientifically independent.



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