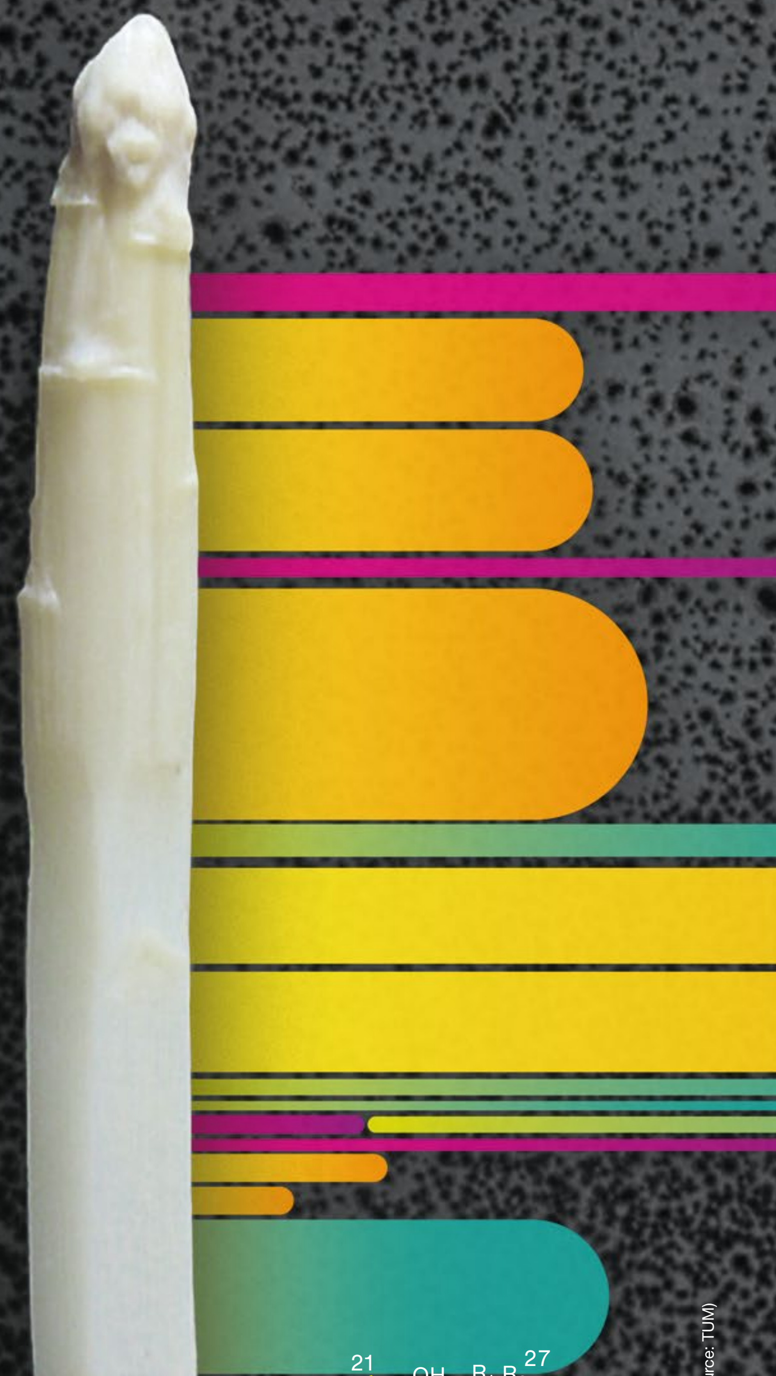
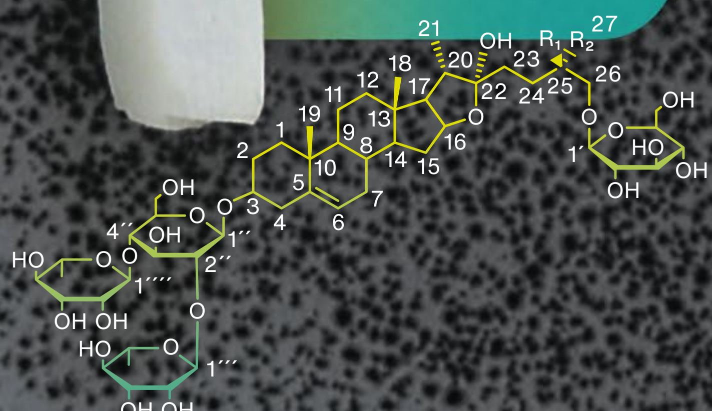
Link
www.molekulare-sensorik.de



Bitter
Astringent
Buttery mouth coating

Asparagus contains around 80,000 chemical constituents, six of them bitter. Prof. Corinna Dawid has tracked them down and identified their chemical structure (example below). Other constituents cause an astringent or – especially at the tips – buttery mouth coating effect reminiscent of melting butter on the tongue.



Picture credit, Graphics: ediundsepp (source: TUM)

The kaleidoscope of good taste

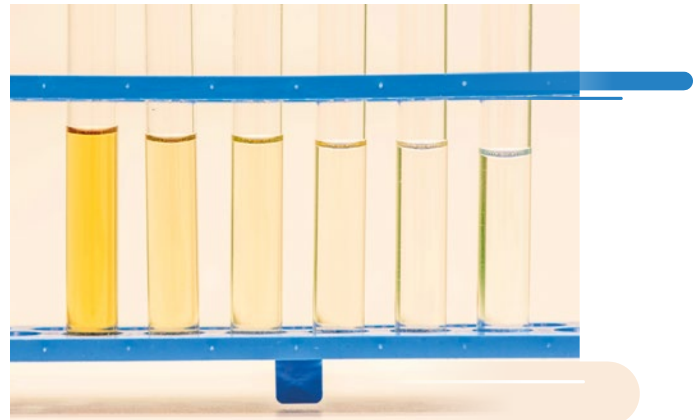
Some foods contain several dozen chemical substances which determine their taste. Separating them from each other and identifying them is a Sisyphean task to which the team working with food chemist Prof. Corinna Dawid has dedicated itself. The researchers work with a mixture of measuring equipment and human tongues.

At the end of the day, human perception is what counts. Trained testers such as doctoral student Sabrina Schalk taste watery solutions of the flavors in different concentrations (see the prepared test tubes, top right). In this way, they can find out the level of dilution at which a bitter substance can be tasted.

The clamp on my nose pinches a bit and makes my voice sound like Donald Duck. "That's the way it has to be," says Christoph Hald apologetically, "because we want to eliminate any olfactory stimuli when we're doing a taste test." The scene of the action is a sensory booth at the Chair of Molecular Sensory Science in the Weihenstephan Science Center. In front of me, there are two rows of eight tubes each. They are filled with water and all look the same but they contain different concentrations of a bitter substance. "We taste them one after the other, from right to left, from low to high concentrations. Use a pipette to suck up a milliliter, let it roll over the tongue but don't swallow it and then spit it out!" explains the young scientist who is taking his doctorate at the Institute.

Not so easy but after a few tries, you soon get the hang of it. My job is to compare two liquids in each case. One contains the bitter substance while the other doesn't. Only the trial leader knows which is which. The first three dilutions all taste the same, of nothing at all in fact. But from the fourth dilution onwards, one of the two liquids tastes distinctly bitter. This identifies the threshold at which the taste receptors can still just perceive the dissolved bitter substance.

What Christoph Hald has just taught me is run-of-the-mill for him – as it is for his roughly 40 colleagues who are researching the taste of food and beverages as (visiting) academics or doctoral students at the Chair for Food Chemistry and Molecular Sensors. This exercise is an integral part of a clever research concept by the name of sensomics. Developed by food chemists in Munich, it is applied today by researchers and food manufacturers across the globe. What's special about it is that it combines precise analyses by high-resolution measuring equipment with the taste perception of human testers. This allows us to take the umpteen thousand substances in red wine, coffee, bread or cheese and identify the precise ones that make up the particular taste of these foodstuffs and beverages. Or to track down disruptive taste notes that make otherwise high-quality dishes inedible.



Bitterness is a warning signal

"If something tastes too bitter, we're alarmed and prefer not to eat it. Because our body has learned since primeval times that bitter plants are often poisonous. After all, this is how the plant defends itself against enemies wanting to eat it and it can be harmful to us too," says Corinna Dawid who is a former doctoral student and today the acting successor to Prof. Thomas Hofmann at the Chair for Food Chemistry and Molecular Sensors. Exceptions prove the rule, as the scientist notes: "Not every bitter substance in a plant is poisonous in the concentrations which we absorb, and we appreciate beverages such as coffee and beer or fruit and vegetables such as grapefruit and radicchio precisely because of their bitter note." In many products, however, a bitter aftertaste is unacceptable – e.g. in pastries, vegetable spreads and synthetic sausages or even in milk substitutes. These and many more foodstuffs could be enhanced with valuable vegetable proteins of pulses, potatoes or corn – if it wasn't for this intrusive bitter taste. For example, large volumes of nutritious vegetable proteins occur today as "byproducts", i.e. as residual products from certain manufacturing processes, which cannot be used for human consumption. Instead they are added to animal feed in low concentrations or serve to produce biogas. ▷

The lighting in the test booths is set in such a way that the tester cannot draw any conclusions as to the taste of the solution from its color.

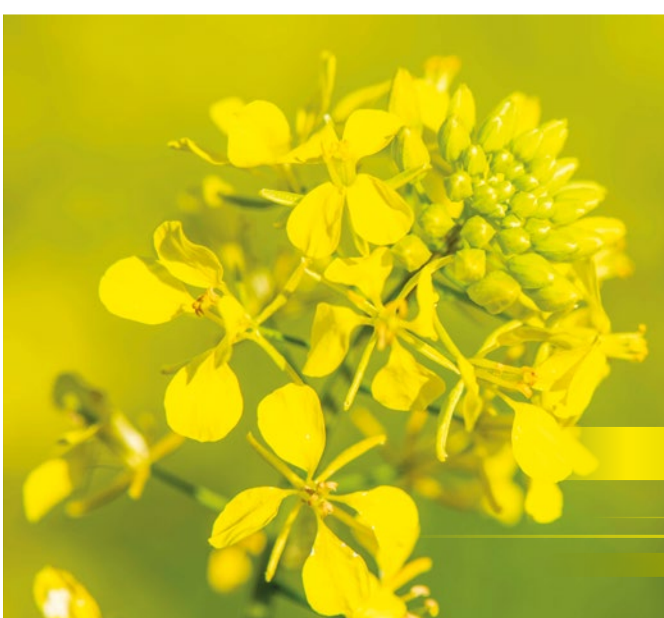
Picture credits: Wolfgang Filser; Graphics: ediundsepp

Six times more agricultural land is required to produce animal protein than for vegetable protein.

6x

The struggle against bitterness

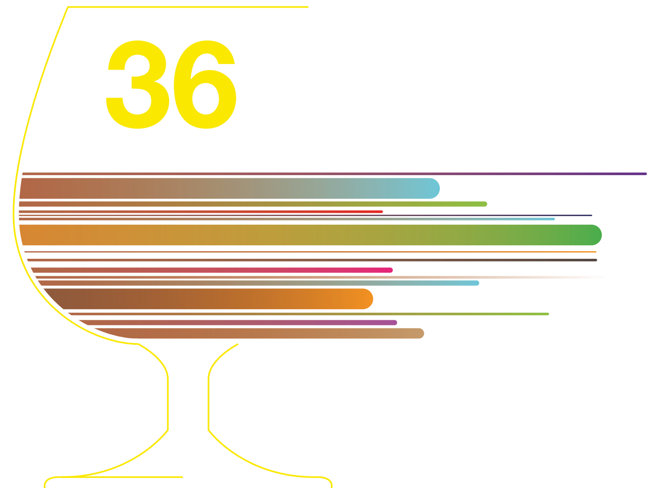
Take the example of rape: In order to extract the coveted cooking oil from the pulses, the ripe seeds are pressed. What's left is the rape cake, which is 30 to 40 percent protein. "Rape protein in combination with other vegetable proteins has an ideal amino acid composition for human nutrition. What's more, its production is sustainable and does not require any additional agricultural land as the plant is cultivated in any case for oil production. For that reason, we should definitely use this source of protein," Corinna Dawid states with conviction. And the fact is that around the world today, six times more land is used for grazing and cultivating animal feed than for producing wheat, fruit and vegetables. Mass livestock husbandry heightens the struggle for the limited arable land on our planet and their flatulence contributes towards a further rise in gases harmful to the climate. Against this backdrop, it seems to be a matter of urgency to develop more vegetable sources of protein for human consumption.



Byproducts of corn and potato processing such as husks and peelings could also serve as a source of valuable fiber in future. However, this poses the same problem as with rape: the purified oat, wheat and potato fiber contains bitter substances which turn out to spoil the taste. "Thanks to our sensomics concept, we have now found out what those substances are. In contrast to rape protein, here we are dealing with a whole bouquet of different bitter substances. We are now searching for ways of removing them to make the fiber edible," Corinna Dawid explains. If we're successful, these new vegetable fibers might one day be used in pizzas and burgers and make them healthier to eat (see also the article on page 20).

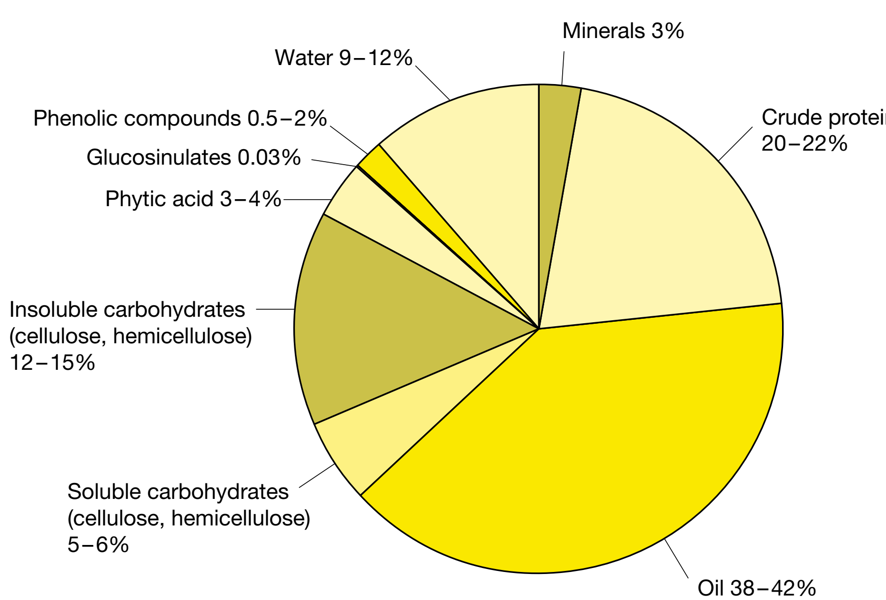
The sensomics concept

Byproducts such as rape, pea or potato protein might play a significant role in this process. To remove or mask their bitter taste, you first have to know which substances are causing it. Christoph Hald has found the main bitter substance in rape – with a lot of hard work and a decent slice of luck. Because as it turned out, it comes from a single substance by the name of kaempferol 3-O-(2‴-O-sinapoyl-ß-sophoroside). The doctoral student discovered and identified the compound with the aid of the sensomics concept. He explains the basic principle as follows. “Firstly, the rape protein is cleaned and split into several fragments by means of various solvents – i.e. sub-groups depending on their solubility. Then the solvents are removed, replaced with water and trained testers taste the product in the sensory booth. This way we can identify the groups containing the bitter substances. Then we subject them to further analysis.” Using ever more sensitive methods, the bitter-tasting fragments are further sub-divided, cleaned and tasted again until finally only those extracts remain that contain the substances we are looking for. “In my case, there was only one fragment left at the end. That was pure chance, as in other food, the bitter taste is caused by a variety of ingredients.” ▷



Of smelling and tasting

Smell and taste contribute equally to the enjoyment of food and drink. The aromas reach our nose and the non-volatile components stimulate the various receptors in our mouth. The first bite or swallow can release further odors which pass over the palate, thus rounding off the overall impression. A few compounds in the right ratios are usually enough to create an unmistakable odor. We recognize butter by just three aromas, while pineapple or strawberry juice require nine and ten, respectively, and beer up to 20 compounds. More complex blends go to make up the aromas of drinks and spirits. Beer contains 17–20 active odorous substances, orange juice and grapefruit juice 22 and 24, respectively. Coffee, red wine and bourbon give off more complex odors with 24 to 27 aromas. The undisputed champions are cognac and brandies, with characteristic bouquets consisting of 36 different components.



One fifth of freshly harvested rape seed consists of high-quality protein. After the oil has been pressed out, the protein percentage in the dried rape cake can be up to 40 percent.

Picture credits: Wolfgang Filser; Graphics: ediundsepp (source: www.depositonce.tu-berlin.de/bitstream/11303/680/1/Dokument_40.pdf)

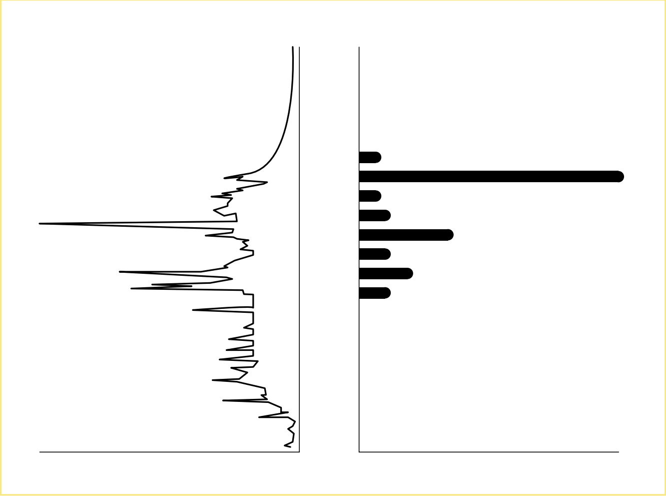
Teamwork between man and machine: The sensomics concept

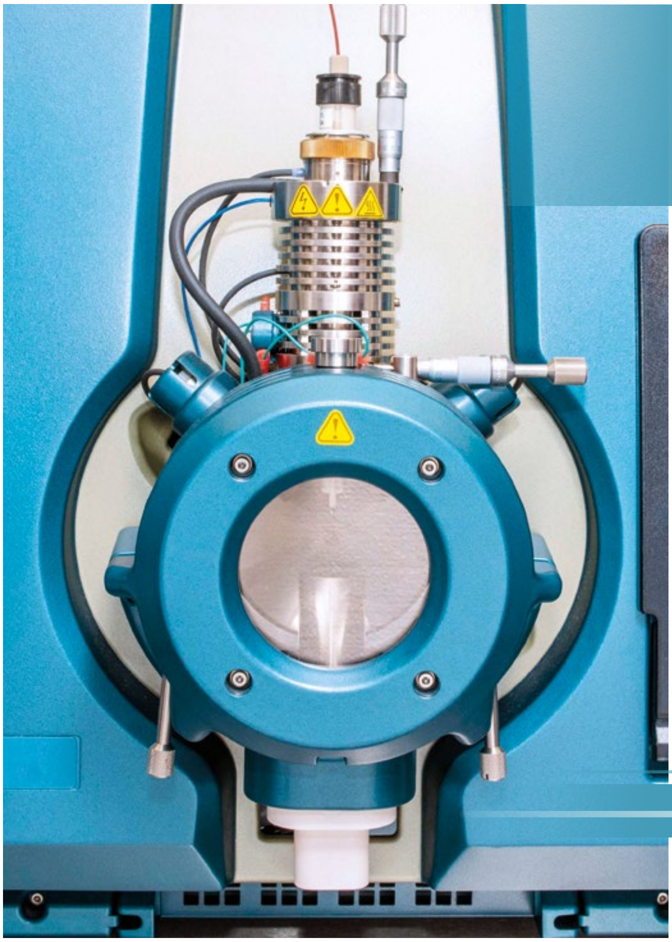
1

Activity-driven fragmentation

A food sample is divided into numerous fragments by means of various solvents. Every fragment undergoes further treatment by high-resolution analytical equipment until all the constituent parts have been separated. Every peak in the curve on the right denotes an individual substance.

At the same time, every fragment is tasted by trained testers in order to track down the constituent parts contributing to the taste. The higher the bar, the more powerful the flavor (bars on the right). Of the umpteen thousand compounds in a foodstuff, typically only a few of them will be of significance for the taste.

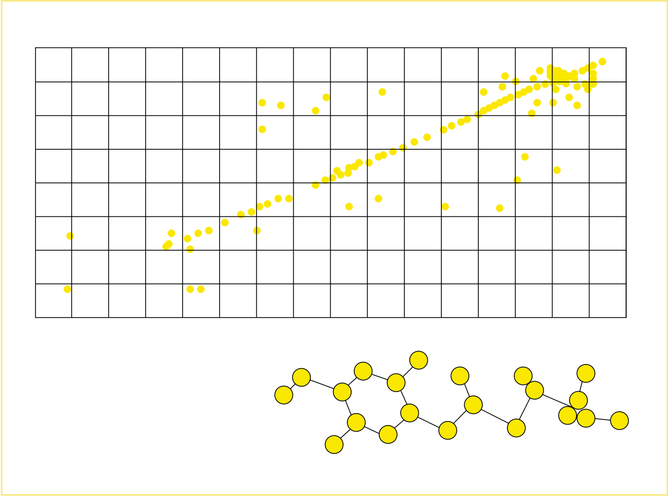




2

Identifying the structure

The challenge now is to identify all the individual compounds tasted by human testers. To do so, the atomic weights are determined in a mass spectrometer (left) and their spatial arrangement defined in the magnetic resonance spectrometer (below).



Picture credits: Wolfgang Filser; Graphics: ediundsepp (source: TUM)

3.

Christoph Hald beside a series of appliances which evaporate the solvent from the flavors. It is then replaced by water.

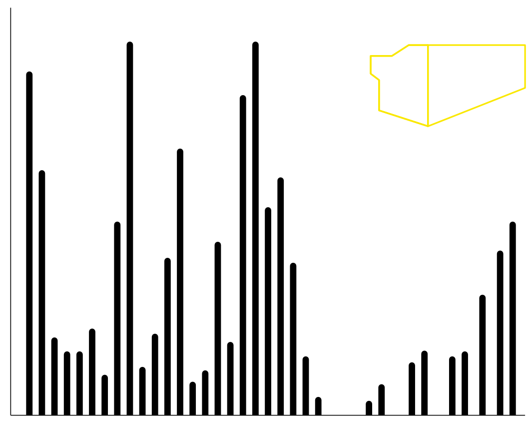
Recombination experiments

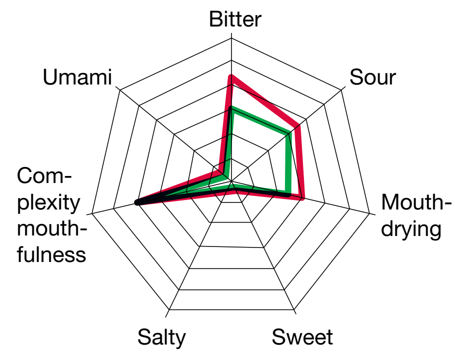
Finally, all the active taste components are combined in their naturally occurring ratios. This recombined product should now exhibit exactly the same taste properties as the genuine food. If the testers are unable to tell the difference between the recombined product and the original, we have pulled it off. But if they can, the search is on for any missing substances or a slightly different composition in the next round.

4.

Quantitative analytics

When all the active taste components have been identified, their natural concentrations and ratios in the food must be determined. This quantification is usually conducted mechanically and demands extremely precise work.





A test is repeated if the results are too different

Successful recombinant

Measurement devices such as mass spectrometers and high-performance liquid chromatographs are available for quantitative analyses to employees at the Chair of Food Chemistry and Molecular Sensory Science.

The principle behind the sensomics concept sounds simple. But applying it requires a huge amount of time and effort in terms of measurement technology. The equipment available in the laboratories for the Chair is suitably impressive, spread over three floors. Various chromatography systems can split minute quantities of a food sample into its constituent parts fully automatically. High resolution mass spectrometers give information on the molecular weights of unknown compounds. In order to reveal the exact structure of substances, there are three nuclear magnetic resonance spectrometers available at the Center for Food Chemistry, operating at 400, 500 and 600 MHz. “These are true high-end appliances,” Corinna Dawid enthuses. According to the acting head of the Chair, this measurement equipment can even be used to investigate scientific questions beyond taste. “We are interested in metabolism and we want to know what happens to food in our body. How much of it arrives in the liver, how much is secreted in urine? Or we work with biologists to measure phytohormones and other vegetable substances. For example, we’re keen to find out what valuable food ingredients are created through abiotic and biotic stress or to what extent their concentration is affected. The applications are almost limitless.” ▷

“The production of rape protein doesn’t require any additional agricultural land.”

Corinna Dawid

Picture credits: Wolfgang Filser;
Graphics: ediundsepp (source: TUM)

How can the bitter taste be removed from rape protein?

Option number 1

We look for bitter blockers which mask the bitter taste, thereby so-to-speak outwitting the sensory cells on our tongue.

Option number 2

The technical process of extracting protein also offers opportunities to wholly or partially remove the kaempferol 3-O-(2´´´-O-sinapoyl-ß-sophoroside). The determining factor is that the concentration of the bitter substance in the final product must be below the taste threshold that humans can still perceive.

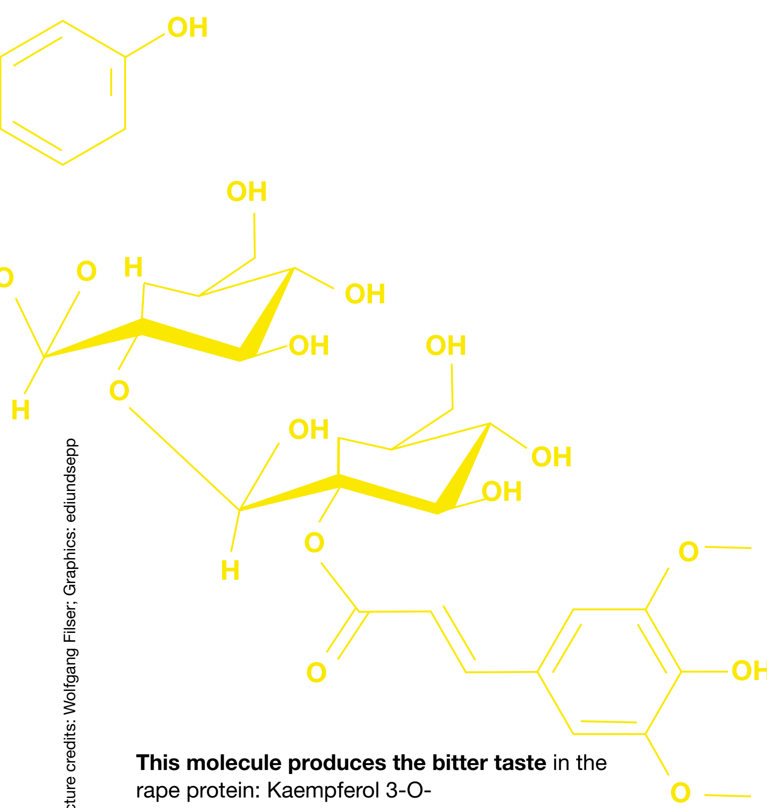
Rape with no bitter substances?

And what happens next to the rape protein after the bitter substance has been identified? “There are two ways of getting rid of the bitter taste. On the one hand, we search for rape strains containing fewer kaempferol derivatives or none at all. To do so, we are currently working with geneticists and breeding researchers in Göttingen, Gießen and Bielefeld as part of a program sponsored by the Federal Ministry of Education and Research. On the other, we are collaborating with an industrial partner in Magdeburg to remove the bitter substance in the technical process to extract the protein. In both cases, we must be able to determine the precise concentration of the kaempferol derivative,” Corinna Dawid explains. The high-resolution analytical equipment is perfectly designed to tackle this task. But even the best measurement equipment has one flaw: it can’t taste. Which means it can’t assess what concentration is relevant to us humans. This crucial job is still being performed by taste testers in sensory booths: from right to left, from low to higher concentrations. Use a pipette to drip a milliliter onto the tongue, but don’t swallow, and then spit it out.

Monika Offenberger

Option number 3

Plant breeders together with geneticists are looking for rape plants that naturally produce less kaempferol 3-O-(2´´´-O-sinapoyl-ß-sophoroside) or none at all. To do so, hundreds of different strains of rape are planted and their bitter substance content tested. Promising strains can be crossed to form elite breeds.



This molecule produces the bitter taste in the rape protein: Kaempferol 3-O-(2´´´-O-sinapoyl-ß-sophoroside)

Picture credits: Wolfgang Filser; Graphics: ediundsepp

Prof. Corinna Dawid

After studying food chemistry at the University of Münster, Corinna Dawid started her doctorate while still in Münster with Prof. Thomas Hofmann. In 2007, she followed her doctoral supervisor to the Weihenstephan Science Center at TUM. During a research stay at the University of Bangkok, she played a pivotal role there in setting up the Institute for Molecular Sensors. Back in Munich, she began her habilitation with studies of stress resistance in plants. After Prof. Thomas Hofmann was appointed TU President, Corinna Dawid took over the Chair of Food Chemistry and Molecular Sensory Science as its acting leader. Since then, her research work has focused again on research into taste and smell.